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by

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ACKNOWLEDGMENTS

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The present study examined pigeons’ responding on token–reinforcement schedules using a two-component multiple schedule with a token-reinforcement schedule in one component and one of several other schedule types in the other. In Experiment 1 responding under a token-reinforcement schedule was compared to that under an equivalent tandem schedule. It was found that response rates under the tandem schedule were higher than under the token and that response patterning in the token-reinforcement schedule was more graded than under the tandem schedule. In Experiment 2 responding under a token-reinforcement schedule was compared to that under a series of brief-stimulus schedule variants. Response rates under brief-stimulus arrangements were higher than under token arrangements, resembling responding in the tandem components from Experiment 1. In Experiment 3, responding under a token-reinforcement schedule was compared to that maintained under several extended-chained schedule variants. Responding was sensitive to reinforcement magnitude, in that response rates were higher under token-schedules than under comparable extended-chained schedules with a single
reinforcer. Weakening the correlation between number of tokens and temporal proximity to reinforcement attenuated the discriminative functions of the tokens. In Experiment 4 responding under a token-reinforcement schedule was compared to that under a procedure that arranged for response-independent tokens and exchange periods, yoked to their occurrence in the previous token component. Response rates were reduced but not eliminated under yoked response-independent token delivery. Only when tokens were removed entirely was responding eliminated. On the whole, the results from all experiments suggest that the tokens may serve a variety of stimulus functions—conditioned reinforcing, discriminative, and eliciting—depending on the contingencies. Further, the data suggest several points of contact between token-reinforcement, extended-chain, and other second-order schedules.
In a token reinforcement procedure, a token (e.g., a coin, a gold star, a check on a list) is provided contingent on a particular response. Tokens are then later exchanged for other reinforcers (e.g., food, access to preferred activities). For example, a child may earn a gold star for every 5 math problems completed, and at the end of the day can exchange the stars at a store for candy or toys; a rat may earn a marble for every 20 responses, and when 10 marbles have been produced can exchange the marbles for food. The tokens have been conceptualized as conditioned (acquired) reinforcers, thought to gain reinforcing value due to their correlation with primary reinforcers. They may also serve important antecedent (discriminative and eliciting) functions, signaling temporal proximity to primary reinforcers. Identifying the conditions under which tokens serve signaling and/or conditioned reinforcing functions is important in a complete account of responding under token-reinforcement schedules. Additionally, understanding token-reinforced behavior is important in that these procedures are often utilized to promote and maintain prosocial behavior in a variety of academic and clinical settings (Kazdin and Bootzin, 1972). Thus, understanding the determinants of behavior in token systems is of theoretical as well as practical importance.

In the first laboratory investigation of token reinforcement, Wolfe (1936) found that chimpanzees would work for tokens exchangeable for food. He initially established discrimination between tokens with and without value by arranging exchange opportunities for one type token (white poker chip) but not for another (brass poker chip).
The chimpanzees were then exposed to a schedule in which a token or food was produced by a response (lifting a weight). Two variants of this schedule were used, one in which the weight lifted was constant and the other where the amount of weight increased following each response. It was found that for both the constant weight and increasing weight conditions, contingent token delivery maintained behavior in much the same way as contingent food delivery, suggesting that the tokens were serving as conditioned reinforcers, acquired through a history of relations with other stimuli.

Cowles (1937) extended the work of Wolfe (1936) by showing that tokens could maintain behavior under conditions with delayed primary reinforcement in which groups of tokens were required to produce exchanges for food. Initially, a single token could be exchanged for food reinforcement. The number of tokens required before an exchange opportunity became available was gradually increased, until long pauses in responding occurred. Responding was consistently maintained under such conditions, with 10-30 tokens per exchange, providing the first demonstration of token reinforcement under intermittent reinforcement schedules. The results showed that tokens could maintain behavior under conditions in which primary reinforcement was temporally distant.

Following two decades of inactivity, token reinforcement procedures were revived by Kelleher’s work in the 1950s (Kelleher, 1956, 1957, 1958). In one study along these lines, Kelleher (1958) exposed chimpanzees to a schedule in which tokens (poker chips) were delivered upon the completion of a fixed-ratio (FR) schedule (FR schedules require a fixed number of responses for completion). Following the delivery of a fixed number of poker chips, the animals were given the opportunity to exchange the chips for primary reinforcement (food). Through the course of the experiment manipulations were made of
the number of responses required to produce a token (token-production schedule) and the number of tokens required before an exchange opportunity (exchange-production schedule). The exchange schedule was held constant at an FR 60 except under the highest token-production schedule value, in which it was reduced to an FR 50. As the token-production schedule was increased from an FR 30 to an FR 125, response rates decreased and pausing increased, during the initial portions of a cycle (when no or only a few tokens had been earned.) Interestingly, when the chimpanzees were given 50 poker chips at the start of a session long pre-ratio pauses ceased, suggesting a potential discriminative function of the tokens. That is, a discriminative function was demonstrated by showing that altering the number of tokens present produced behavior early in a cycle that was typically seen later in a cycle.

Later studies maintained this emphasis on conditioned reinforcement and temporal organization of behavior. Malagodi (1967) examined rats’ responding on FR 20 token production schedules, with marbles as token reinforcers. During exchanges, tokens could be deposited in a receptacle with each deposit producing a food pellet. Fixed numbers of tokens were required to produce exchange periods, with this number varying from 1 to 8 across groups of sessions. Similar to the token-production effects reported by Kelleher (1958), as the exchange requirement was increased, response rates decreased and pausing increased.

Waddell, Leander, Webbe, and Malagodi (1972) examined rats’ responding on a schedule in which tokens (marbles) were produced according to an FR 20 and exchanged according to a fixed-interval (FI) schedule that varied across conditions. (Fixed-interval schedules arrange for a consequence to occur following the first response after a set time
interval has expired). Response patterning within the FR 20 token-production schedules were similar to that seen under simple FR schedules, a pre-ratio pause followed by rapid rates of responding. Response rates across token-production segments within the exchange cycle were similar to those seen under simple FI schedules: the rate of FR token-production sequences increased in proximity to food. Also similar to simple FI schedules, overall response rates decreased as a function of FI duration.

In a similar vein, Webbe and Malagodi (1978) examined rats’ responding on FR 20 token reinforcement schedules with FR or variable ratio (VR) schedule of exchange production. (Variable ratio schedules deliver a consequence after a number of responses have been emitted, with the number of responses required varying around some preset average). Across a series of conditions, the exchange schedule alternated between a VR 6 and FR 6. They found that response rates were higher, and pre-ratio pauses were lower, under the VR exchange schedule when compared to the FR exchange schedule. These results are in accord with behavior maintained under simple FR and VR schedules. However, only one VR and FR exchange value and only one token production value were used.

Foster, Hackenberg, and Vaidya (2001) extended the work of Webbe and Malagodi (1978) by examining the influence of exchange-production schedule type and value on token-reinforced behavior. They also extended prior work by using a different species (pigeons) and different token reinforcers (lights mounted in a horizontal row above the response keys in an otherwise standard conditioning chamber). (Such non-manipulable tokens have a number of advantages with respect to examining stimulus functions of tokens, as described in more detail below.) In their experiment, the value of the FR and
VR exchange schedule was varied across conditions from 1 to 8 while the token-production schedule was held constant at FR 50. Response rates decreased and pausing increased, as a function of ratio size under both schedules. Consistent with the results of Webbe and Malagodi (1978), response rates under the VR exchange were less affected by changes in ratio value than those under the FR schedule. This effect, combined with results reported in the studies discussed above, provide strong evidence that in token-reinforcement schedules the schedules in place for token production and exchange each influence behavior in a manner similar to that of analogous simple schedules in isolation.

Bullock and Hackenberg (2006) examined the role of both the token-production and exchange-production schedules in a token reinforcement procedure with pigeons. Prior research has typically assessed the effect of manipulating either the token production or exchange schedule in the context of a fixed value of the other. Bullock and Hackenberg (2006), however, examined the token production and exchange schedules with both varied across a range of values. Comparable to FR performance under simple schedules, response rates decreased as the token-production FR was increased within a given exchange value. Further, decreases in response rates under the larger FR token-production schedules were even more pronounced under higher exchange schedules. Similarly, within a given token-production value, increases in the exchange schedule produced decreases in response rates, particularly under higher token-production values. Under the higher exchange-schedule values, responding within an exchange cycle was graded, with low responses rates early in the cycle increasing as more tokens were earned. These results indicate that the effects of token production and exchange-schedule manipulations vary depending on the value of the other schedule. Under lower token-
production schedules, increases in exchange-schedule value had less of an effect than under higher token-production schedules. However, because the study was not designed to assess stimulus functions of the tokens directly, more precise statements about the function of the tokens were limited.

**Purpose of the Present Research**

Although the studies discussed above demonstrated several important determinants of responding under token-reinforcement procedures, they failed to isolate the stimulus functions of the tokens. There are at least three potential functions of stimuli in token reinforcement schedules: discriminative, reinforcing, and eliciting. Previously neutral stimuli can gain a discriminative function via their temporal correlation with primary reinforcement. In other cases stimuli can serve as conditioned reinforcers due to their correlation with a reduction in delay to or increase in magnitude of primary reinforcement (Gollub, 1970). A third function is suggested by research on serial autoshaping in which stimuli correlated with the presentation of food delivered under some response-independent time-based schedule can elicit responding (Ricci, 1973).

The present research investigates the potential controlling variables discussed above. The basic methodological strategy was to compare and contrast token schedules with other reinforcement schedules which have proven useful in revealing stimulus function. For example, in order to examine if tokens have an effect on behavior one could compare behavior maintained by a token-reinforcement schedule to a similar schedule in which they were absent. In the present research, stimulus functions were examined by using schedules which were similar to token-reinforcement schedules but had particular features useful for comparison purposes. The following section provides a brief overview of these schedules and their relation to the present issues.
Schedules as Tools for Investigating Stimulus Function

Token schedules have been conceptualized as second-order schedules of reinforcement, or “schedules of schedules” with the behavior that produces tokens considered a unitary response that is itself reinforced according to some other schedule (Kelleher, 1966). For example, under a second order FR 4 (FR 10) schedule, the first-order schedule required 10 responses to produce a token and the second-order schedule required 4 tokens before an opportunity to exchange these tokens for food was presented; the FR 10 token production schedule can be conceptualized as a unitary response that is itself reinforced according to an FR 4, hereafter termed an FR 4 (FR 10) token-reinforcement schedule. Several types of second-order schedules have stimulus arrangements potentially useful for revealing the function of tokens.

The conventional second-order schedule involves brief-stimulus presentation (e.g., a flash of light, a tone) contingent on the completion of a first-order schedule requirement and primary reinforcement contingent on completion of the second-order schedule requirement (Gollub, 1970). A token reinforcement schedule differs from this more conventional arrangement in that completion of the first-order schedule requirement produces a stimulus that remains present throughout the duration of the second-order schedule. In addition, the number of stimulus presentations in a token-reinforcement schedule is directly correlated with the magnitude of reinforcement available upon completion of the second-order schedule.

Second-order schedules are part of a larger family of sequence schedules that also includes chained schedules. Chained schedules are schedules that arrange for the presentation of a stimulus following the completion of some simple schedule (link), with primary reinforcement delivered after the completion of a number of links. Unlike token-
reinforcement schedules, in chained schedules each successive link may have a different response requirement and a distinct stimulus is present during each link. Further, similar to brief-stimulus schedules, in chained schedules there is no correlation between number of simple schedules completed and magnitude of reinforcement. However, when chained schedules have the same simple schedule in each link, the simple schedule becomes analogous to the first-order schedule in token-reinforcement and brief-stimulus schedules. Comparing and contrasting behavior maintained under token reinforcement schedules to that maintained under brief-stimulus and chained schedules allows for an examination of the effects of stimulus duration, stimulus accumulation, and a correlation with number of stimulus presentations and primary reinforcer magnitude.

According to Kelleher and Gollub (1962), the effects of stimuli in chained or second-order schedules on responding are difficult to assess. First, the subject may not be attending to the stimuli presented in the second-order schedule (in this case tokens), in which case behavior would be a function of the contingency between responding and reinforcement. Further, responding in the presence of a segment of a token-reinforcement procedure could be due to the temporal proximity of that segment to primary reinforcement, the conditioned reinforcing value of the token that responding has produced in the past, or both. Finally, response rates could be due to some property of the stimuli themselves, apart from that gained via operant contingencies. Given these possibilities, statements about the functions of tokens in token reinforcement procedures require appropriate control procedures.

One method for assessing whether the stimuli in second-order schedules are having an effect is to employ an equivalent tandem schedule. A tandem schedule, when used as
a control condition, typically arranges for the segment response requirements and
schedules to be identical to those of the second-order schedule of interest with the
exception that there are no discriminative stimuli denoting the completion of a given
segment (Kelleher & Gollub, 1962). For example, Kelleher (1966) examined pigeons’
responding under a second-order schedule in which 30 consecutive FI 2-min schedules
were required for food reinforcement. In this procedure, following the completion of
each FI 2-min schedule, a white key light was briefly illuminated. In order to assess the
effects of the key-light flashes, a tandem procedure was employed in a separate condition
in which the schedule requirement and the total reinforcement were identical, but no
stimuli were presented following the completion of the FI schedules. If the stimuli have
some effect on behavior one would expect differences in performance between the
second-order and tandem procedures. In Experiment 1 of the present investigation, we
compared performance from a token-reinforcement schedule to that of a tandem schedule
equivalent in all respects except for the tokens. Any difference in responding between
the token and tandem schedules would demonstrate that the presence of the tokens have
an effect on behavior.

As mentioned earlier, the stimuli in brief-stimulus schedules differ from those in
token-reinforcement schedules with respect to the duration of presentation, accumulation,
and correlation between stimulus number and position with responses and time before
primary reinforcement. A modified token-reinforcement schedule, modeled after a brief-
stimulus schedule, can thus serve as a basis of comparison to assess the importance of the
procedural differences between token-reinforcement and brief-stimulus schedules in
determining stimulus function. In one condition the briefly-presented token schedule was
identical to that of the token schedule with the exception of presentation duration. In a second condition the tokens did not accumulate, rather a single token was presented with its position changing. In a third condition, performance on a token-reinforcement schedule was compared to that under one that simply flashed all four tokens. Differences in responding between the 3 briefly-presented token-schedule variants would indicate the importance of manner of stimulus presentation while differences between the standard and briefly-presented token schedules would indicate the importance of stimulus duration.

Another method of assessing the functions of stimuli in second-order schedules involves altering the order of presentation (Kelleher & Gollub, 1962). Varying the order by which stimuli are presented in a token-reinforcement schedule may provide information concerning the importance of a correlation between number of tokens and temporal proximity to food as a response determinant. For instance an FR 4 (FR 50) schedule of token reinforcement was used as a standard for comparison in Experiments 2, 3, and 4 of the present study. Under this schedule every 50 responses would illuminate a token, with the illumination of the fourth token preceding reinforcement. In Experiment 3 of the present investigation, two of the conditions involved an alteration in the manner of token presentation, the results of which were compared to the standard token schedule. In one condition the stimulus order was reversed such that a cycle began with four tokens illuminated that darkened in reverse order as each segment was completed. If the absence of tokens had an effect on responding in link one, then the reversed order condition should produce a change in behavior early in the cycle. Another condition in Experiment three involved tokens illuminating according to a VR 50 schedule but with
the token exchange still occurring after 200 responses and still delivering four food reinforcers. The VR contingency was designed to weaken the correlation between number of tokens and proximity to reinforcement. If the contingency was an important determinant of the effects of the tokens, then the VR token production condition should produce responding more like that under the tandem conditions.

Altering the contingencies by which stimuli are presented in second-order schedules allows assessment of the degree to which these stimuli, in addition to their response-dependent presentation, might affect behavior. If the tokens are presented response independently, yoked to their temporal occurrence under the regular procedure, the role of any possible respondent (eliciting) functions of the tokens could be assessed. For instance, if while under an FR 4 (FR 25) schedule of token reinforcement, a pigeon earned the first token after 60s, the second after another 45s, the third after another 30s, and the last after another 15s, then under the yoked procedure, the tokens would be presented at these temporal intervals, irrespective of responding. The fourth experiment of this study uses just such an arrangement, with the first and third components of a session comprised of the standard token-reinforcement schedule, while the second and fourth components had a schedule in place in which the tokens and exchange periods were presented independently, yoked to their temporal occurrence in the previous component. In this case it may be that responses were elicited due to the temporal relationship between token presentation and food (Ricci, 1973).

Lastly, a method generally employed in the present series of experiment to assess stimulus function in second-order schedules involved the use of a multiple schedule (Kelleher and Gollub, 1962). A multiple schedule involves some manner of alternation
between two schedules, each presented independently with a distinct discriminative stimulus. Throughout the present study a two-component multiple schedule was employed, allowing for the comparison of a token-reinforcement procedure with some other schedule within each condition.

Taken together the experiments reported here were designed to examine under what conditions functions of tokens in token-reinforcement schedules can have conditioned-reinforcing, discriminative, and eliciting functions. In particular, findings from experiments involving added-stimulus schedules, extended-chain schedules, token-reinforcement schedules, and serial autoshaping procedures suggest that the functions of these stimuli may vary depending on how they are related to the schedule of primary reinforcement. The present studies were designed not only to examine stimulus function in token-reinforcement schedules, but to also allow for points of contact between and give a broader account of the functions of stimuli in second-order and extended-chained schedules. The results of the present experiments thus lend themselves both to a better understanding of token-reinforcement schedules and to a broader conceptualization of how determinants of behavior under token-reinforcement schedules relate to those of other forms of second-order schedules.
CHAPTER 2
EXPERIMENT 1

Previous research on schedules of token reinforcement has shown that response rates vary inversely with the value of FR token production and exchange schedules (Foster et al., 2001; Webbe and Malagodi, 1978). Bullock and Hackenberg (2006) showed that the relationship between response rates and FR exchange-schedule value varies depending on the value of the FR token–production schedule. Foster et al., (2001) found schedule-typical patterns under token production and exchange schedules, suggestive that the tokens had some function. However, tandem-control conditions would allow for a more precise characterization of that function (or functions).

An experiment investigating extended-chain schedules by Jwaideh (1973) serves as an example of utilizing tandem-control conditions to examine stimulus functions and serves as a potential point of contact between token reinforcement and extended-chain procedures. Pigeons were exposed to a series of chained schedules, each with an accompanying equivalent tandem schedules (same response requirement as a chained schedule but with no stimuli delineating transitions between schedule components, or links). The number of links in the chain was varied from 1 to 5 with FR schedules in each link. The total response requirement to complete all links was varied from 12 to 240. Two additional conditions were conducted, one in which the order of the chain sequence was reversed and the other in which the terminal stimulus in the chain was also used in the initial link. Performance under the chained schedule was compared to that of the equivalent tandem schedule to assess any potential functions of the stimuli. That is,
response requirements were identical in the two schedules; the only difference was whether each link was (chained) or was not (tandem) correlated with a distinct stimulus. Overall response rates decreased and pre-ratio pausing increased, both as a direct function of the number of components and the number of responses to reinforcement. Further, response rates under tandem conditions were generally higher than equivalent chained conditions. Reversing the order of the stimuli in the chain resulted in initial increases in response rates that soon returned to those seen previously under the normal chained schedule. When the same stimulus was used for the first and last link of the chain, however, pre-ratio pausing decreased and remained shorter than under the regular chain procedure. The author suggested that differences in performance under the tandem and chained schedules demonstrated a function of the stimuli. It was suggested that stimuli early in the chain came to produce low rates of responding due to their correlation with long delays to reinforcement, while stimuli in the later links of the chain produced higher rates of responding due to their correlation with short delays to food.

The experiment by Jwaideh (1973) had the same FR schedule for each link in the chain and a fixed number of links in the chain per condition. Because the requirement for each link was constant, each link could be conceptualized as analogous to a token-production segment. Further, the fixed number of links required to produce reinforcement is analogous to an FR exchange schedule. The main differences between the procedure used by Jwaideh (1973) and a token schedule are that in the latter procedure (a) the number of tokens earned is correlated with the magnitude of reinforcement (number of food deliveries during an exchange period), and (b) the tokens accumulate in continuous fashion rather than having a distinct stimulus accompany each link of a chain schedule.
The accumulation of tokens in token reinforcement procedure resembles stimulus presentation of another form of second-order schedule, an added-stimulus schedule (Zimmerman & Ferster, 1963, 1964), which provides a further point of contact with token-reinforcement schedules. Zimmerman and Ferster (1964) examined responding under an added-stimulus schedule where pigeons’ responding on the left of two keys resulted in a houselight flash and a voltmeter (a gauge that could be displaced from zero to maximum of an 80 degree arc) incrementing towards a terminal position, with stimulus changes reinforced according to a variable-interval (VI) schedule (VI schedules arrange for a consequence to occur contingent on the first response following some period of time that varies around a preset average). Once the voltmeter had been fully displaced, the right key became operative, and each subsequent peck produced food (one per voltmeter increment). The VI schedule by which the voltmeter incremented (VI 1 min and VI 3 min), the number of increments required to reach the maximum (FR 10 and FR 20), and the presence/absence of the voltmeter and houselight stimuli were varied systematically across conditions. Response rates were initially low and accelerated with the number of voltmeter increments or temporal proximity to primary reinforcement. Increasing the number of steps for the voltmeter from FR 10 to FR 20 decreased response rates across both the VI 1 min and VI 3 min increment schedules, an effect similar to that of increasing the exchange schedule in token-reinforcement schedules (Bullock and Hackenberg, 2006; Foster et al, 2001). The removal of the voltmeter advance and houselight flash following the completion of each VI (tandem schedule) resulted in a more constant rate of responding across the cycle. These results suggest that the added stimuli served a discriminative function similar to the link stimuli used in extended chained schedules (Jwaideh, 1973).
The present experiment used a token-reinforcement procedure similar to that of Bullock and Hackenberg (2006) and Foster et al. (2001). In keeping with the suggestions of Kelleher and Gollub (1962) that a multiple schedule can serve as part of a control procedure to investigate the functions of stimuli in second-order schedules, the present procedure utilized a two-component multiple schedule. One component of the multiple schedule was comprised of a token-reinforcement schedule and the other component a tandem schedule with otherwise identical contingencies. The token-production schedule remained constant at FR 50, a value at which graded patterns of responding across successive token-production segments have been seen in prior research. This graded pattern is an important indicator of discriminative functions of added stimuli such as tokens. The exchange-production FR was varied across conditions in a manner consistent with prior research in our laboratory (Bullock & Hackenberg, 2006; Foster et al., 2001). The present experiment is thus a systematic replication (Sidman, 1960) of our prior work, but with tandem-control conditions to assess the stimulus functions of the tokens.

Half the pigeons in this experiment were exposed to small tokens (light emitting diodes, or LEDs) while the other half were exposed to larger tokens (jeweled stimulus lights, 1.5 cm in diameter). Prior published work on token-reinforcement schedules in our laboratory used the small-token preparation (Foster et al., 2001; Foster & Hackenberg, 2004; Hackenberg & Vaidya, 2003; Jackson & Hackenberg, 1996), but we had suggestive evidence of more pronounced and systematic effects from the larger tokens. A comparison of the effect of token size on performance under token-reinforcement schedules allowed for an assessment of whether the physical properties of the tokens themselves would produce differential discriminative effects (see Gollub, 1970, for a
discussion of the effects of stimulus properties in second-order schedules of briefly-presented stimuli).

In sum, the purpose of Experiment 1 was to (a) assess stimulus functions of the tokens by comparing directly performance under token and equivalent tandem-control conditions, (b) replicate previous findings of exchange-production FR manipulations, and (c) evaluate the effects of token size/salience on token-reinforced behavior.

Method

Subjects

Six White Carneau pigeons (*Columba livia*) (numbered 907, 83, 832, 999, 910, 47) served as subjects. Pigeon 832 had prior experience with token-reinforcement schedules. Pigeons were individually housed under a 16.5 hr / 7.5 hr light:dark cycle and had constant access to water and health grit in home cages. Pigeons were maintained at 80% ± 20 g of their free-feeding weights with supplemental post-session feeding.

Apparatus

Two standard three-key pigeon chambers with a modified stimulus panel served as the experimental apparatus. The first chamber (large token chamber) was 35 cm high by 31 cm long by 34.5 cm wide, and had a stimulus panel with three response keys centered horizontally 10 cm from the ceiling to the key center and 8 cm from the adjacent key(s) (center to center). Further, a row of 12 evenly spaced stimulus lights with red caps, approximately 1.5 cm in diameter, was centered 7.5 cm above the response keys (center to center) and protruded 1.3 cm into the enclosure. The stimulus lights were always illuminated left to right, in sequential order, and served as tokens in this arrangement. Food was delivered through an opening centered 10.5 cm under the center key
(approximately 5.5 cm wide and 5 cm tall). This box was also equipped with a Sonalert® that provided an auditory stimulus (0.1 s tone) that accompanied token onset and offset.

The second chamber (small token chamber) was 36 cm high by 50 cm long by 36 cm wide and the intelligence panel had 3 response keys centered vertically 11.5 cm from the ceiling to the key center and 9 cm from each other (center to center). For this chamber, a stimulus array of 34 red, evenly spaced, light-emitting diodes (LEDs), 0.4 cm in diameter, were centered 5 cm above the keys and 1.25 cm apart from each other (center to center) and protruded 0.3 cm into the enclosure. The LEDs were always illuminated left to right, in sequential order. An electromechanical stepping switch (Lehigh Valley Electronics®, Model 1427) located on top of the chamber controlled LED illumination, the operation of which also provided auditory feedback each time a token was presented or removed. A food hopper opening was centered 11.5 cm below the left key (approximately 5.5 cm wide and 5 cm tall).

Both chambers had a houselight centered above the token array that provided diffuse illumination. When operative, side keys were illuminated green or yellow, and the center key red. Pecks with a force between approximately 0.11-0.14 N (small token box) and 0.13 N (large token box) were counted. A solenoid-operated hopper could be raised into the food opening, allowing access to mixed grain. A white light inside the hopper illuminated during the food presentation. A photo-beam recorded head entry into the hopper. Continuous white noise and ventilation fans were active during experimental sessions to mask extraneous sounds. In a separate room a computer equipped with Med-PC® software controlled experimental events and collected data.
Procedure

**Preliminary Training.** All pigeons were exposed to a series of training conditions (data not shown) prior to Experiment 1. Naive pigeons were initially adapted to the experimental chamber with the houselight illuminated and trained to eat food from the grain hopper. For birds with no history of key pecking, pecks to the center key were shaped via reinforcing successive approximations. All birds were then exposed to an FR 1 schedule in which pecks on the red illuminated center key produced food access. This was followed by sessions in which the left side key illuminated; a peck on this key would darken the side key and illuminate the center key, a peck on the center key would darken the center key and produce food reinforcement. This training arrangement lasted until birds were reliably pecking the side and center keys. This was followed by exposure to a multiple schedule with an FR 100 in effect during both components. Each bird was then exposed to several days of token-food pairings. These sessions consisted of the alternating illumination of the left side key within a session (randomly yellow or green). After the side key was pecked (FR 1) a token was illuminated and a tone was sounded, after which the side key darkened and the center key illuminated. A peck on the center key resulted in the darkening of one token and 1.5 s of food (timed from head into hopper). These sessions lasted for 64 reinforcers and were in effect for 3-4 days.

**Standard Procedure.** Each session consisted of a 2-component multiple-schedule with two exposures to each component. Components occurred in a pseudo-random order, with a component remaining in effect for 16, 1.5-s food deliveries. Components were separated by 30 s blackouts, or intercomponent intervals. Sessions began with the illumination of the white houselight and left key (either green or yellow depending on component type with colors counterbalance across birds). Conditions lasted for at least 14
sessions and until response rates were deemed stable via visual inspection of overall responses per minute for each component. Data were generally considered stable when no monotonically increasing or decreasing trends and the highest or lowest points were not present in the last 5 sessions of a condition.

During the token components, tokens were earned according to an FR 50 token-production schedule (i.e., 50 responses produced one token) and exchanged according to an FR exchange-production schedule that varied systematically from FR 2 to 8 across conditions. Tokens were illuminated left to right. Completing the exchange ratio requirement produced an exchange period, during which the left key darkened and the center key illuminated red. A single response on this key darkened the rightmost token and raised the food hopper for 1.5-s. This exchange period remained in effect until all tokens earned that cycle had been exchanged for food. The period was followed by an immediate return to the token-production cycle (left key illuminated) or the inter-component blackout. After the ratio was completed and the exchange period initiated for the tandem component, a number of tokens equal to that in the token component was illuminated. The response requirement and token-exchange stimulus conditions were otherwise identical for the tandem and token components with the exception that no stimulus change occurred within the ratio under the tandem schedule (i.e., a fixed-ratio schedule). Table 2-1 lists the order of conditions and number of sessions per condition. Key colors were reversed under replications.
Table 2-1. Order of conditions and number of sessions per condition for Experiment 1. Listed are the token schedule, but each condition also included a tandem schedule. The superscript \( a \) denotes a color reversal, the superscript \( b \) denotes conditions conducted in large token box, while an * denotes that a condition was not completed. Number of sessions per condition is listed in parentheses.

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>Small Tokens</th>
<th>Large Tokens</th>
</tr>
</thead>
<tbody>
<tr>
<td>832</td>
<td>FR 2([50]) (17)</td>
<td>FR 2([50]) (19)</td>
</tr>
<tr>
<td>910</td>
<td>FR 4([50]) (22)</td>
<td>FR 4([50]) (28)</td>
</tr>
<tr>
<td>999</td>
<td>FR 4([50]) (22)</td>
<td>FR 4([50]) (39)</td>
</tr>
<tr>
<td>47</td>
<td>FR 8([50]) (37)</td>
<td>FR 4([50]) ( a ) (15)</td>
</tr>
<tr>
<td>83</td>
<td>FR 8([50]) (37)</td>
<td>FR 4([50]) ( a ) (19)</td>
</tr>
<tr>
<td>907</td>
<td>FR 8([50]) (37)</td>
<td>FR 4([50]) ( a ) (46)</td>
</tr>
</tbody>
</table>

Results

Figures 2-1 and 2-2 show for each pigeon the means and standard deviations of the running response rates (response rates factoring out pre-ratio pausing) and pre-ratio pausing, respectively, as a function of exchange-production ratio across the final 5 sessions of each condition. Graphs in the left and right columns show data for pigeons typically exposed to the smaller and larger tokens, respectively. Filled points represent data from token components, open points data from tandem components, with unconnected points denoting replications. The final conditions for several birds were replications across chamber type. Thus, for 1 condition 907 was run in the small token chamber while for 1 condition 999 and 832 were run in the large token chamber. Data from these conditions are denoted by squares.

Response rates varied inversely, and pre-ratio pausing varied directly, with the value of the exchange-schedule ratio for both token and tandem components. Further, for 4 out of 6 pigeons response rates in the tandem components were generally higher and pre-ratio pausing lower than rates in the token components (the exceptions being 999 and 832).
Differences in performance under the tandem and token components were greater for birds exposed to the larger tokens.

Figure 2-1. Mean responses per minute (not including pre-ratio pause) and standard deviations plotted as a function of exchange ratio from the last 5 sessions of a condition. Left panels show the data from subjects primarily run in the small token box while right panels show data for subjects primarily run in the large token box. Open symbols represent data from tandem components, closed from token components; disconnected symbols represent replications, and while squares represent data from replications across different chambers and token sizes.
Figure 2-2. Mean pre-ratio pausing and standard deviations plotted as a function of exchange ratio from the last 5 sessions of a condition. Note that the y-axis is logarithmic. Left panels show the data from subjects primarily run in the small token box while right panels show data for subjects primarily run in the large token box. Open symbols represent data from tandem components, closed from token components, disconnected symbols represent replications, while squares represent data from replications across token type.
Figures 2-3 and 2-4 show response rates as a function of segment (the ordinal position within the exchange-production cycle) for pigeons exposed to the small and large tokens, respectively. Figures 2-5 and 2-6, organized similar to Figures 2-3 and 2-4, show pre-ratio pausing as a function of token segment for all pigeons (amount of time in seconds between token illumination and a response). For Figures 2-3 through 2-6, filled and open circles represent performance under token and tandem components. The large dashed lines represent replications within a token type while the small dashed lines are indicative of replications across chambers (token type). For both tandem and token components across all exchange production schedules, initial-segment rates generally were low and increased as a function of number of tokens earned (Figures 2-3 and 2-4). Pre-ratio pausing was largest for the initial segment and, with a few exceptions, decreased to a small value in the later segments (Figures 2-5 and 2-6). Responding in the tandem components was characterized by low initial-segment rates that gave way to high, constant rates of responding. Responding in the token component was characterized by low initial-segment rates gradually increasing as a function of the number of tokens earned. In summary, these figures show that differences in performance under token and tandem components were comprised of both lower running response rates and longer pausing in the early segments of a token cycle.
Figure 2-3. Mean within ratio responses per minute (not including pre-ratio pause) plotted as a function of token production segment, for subjects run primarily in the small token box, from the last 5 sessions of a condition. Points from tandem components represent successive 50 response segments. Open symbols represent data from tandem components, closed from token components, solid lines represent original exposures, large-dashed lines represent replications, and small-dashed lines represent replication across token size.
Figure 2-4. Mean within ratio responses per minute (not including pre-ratio pause) plotted as a function of token production segment, for subjects run primarily in the large token box, from the last 5 sessions of a condition. Points from tandem components represent successive 50 response segments. Open symbols represent data from tandem components, closed from token components, solid lines represent original exposures, dashed lines represent replications, and squares represent replication across token size.
Figure 2-5. Mean pre-ratio pausing plotted as a function of token production segment, for subjects run primarily in the small token box, from the last 5 sessions of a condition. Points from tandem components represent successive 50 response segments. Open symbols represent data from tandem components, closed from token components, solid lines represent original exposures, large-dashed lines represent replications, and small-dashed lines represent replication across token size.
Figure 2-6. Mean pre-ratio pausing plotted as a function of token production segment, for subjects run primarily in the large token box, from the last 5 sessions of a condition. Points from tandem components represent successive 50 response segments. Open symbols represent data from tandem components, closed from token components, solid lines represent original exposures, large-dashed lines represent replications, and small-dashed lines represent replication across token size.
Discussion

This experiment investigated behavior maintained under token-reinforcement schedules and equivalent tandem controls. The experimental design allowed for assessment of the effects of tokens under several different exchange-schedule values by parametrically manipulating the exchange schedule across conditions. The primary findings from this experiment, as shown in Figures 2-1 and 2-2, were (a) response rates varied inversely, and pre-ratio pausing directly, with the token production schedule FR value, replicating previous finding concerning exchange schedule manipulations (Bullock and Hackenberg, 2006; Foster et al., 2001; Webbe and Malagodi, 1978), (b) the presence of tokens reduced response rates, and increased pre-ratio pausing, when compared to their absence, and (c) the presence of the tokens engendered a more graded pattern of responding than when they were absent (see Figures 2-3 and 2-4), similar to that seen under extended-chained schedules (Jwaidah, 1973). Lastly, for pigeons exposed to the larger tokens the size of the differences in response rates between the token and tandem components was generally greater, and more consistent, than for pigeons exposed to the smaller tokens.

Response rates for pigeons exposed to the larger tokens were higher in most cases under the tandem components than in the accompanying token components under the larger tokens. This result indicates a possible discriminative effect, similar to that reported by Jwaidah (1973) with extended-chained schedules. Figure 2-2 shows that lower overall response rates in the token schedules were primarily a function of long pre-ratio pauses and low response rates in the early links. This result is remarkably similar to that of Jwaidah (1973) and fits within her interpretation that the stimuli in the initial links
of the chain (tokens, in the present experiment) served as discriminative stimuli associated with longer delays to primary reinforcement.

The interpretation that the tokens primary function was discriminative is further supported by examination of response patterns across segments within an exchange cycle (Figures 2-3 and 2-4). Under simple FR schedules (tandem components in the present experiment) response patterning generally consisted of a pre-ratio pause followed by high, relatively constant rates of responding. However, as shown in Figures 2-3 and 2-4, under the FR 4 and FR 8 exchange schedules (middle and right columns), response patterning within an exchange cycle under the token-reinforcement component was graded with low rates in early segments increasing as more tokens were earned. The response patterning found in the present experiment is once again consistent with the results of Jwaidah (1973) and supports the interpretation of the tokens in the early segments serving a discriminative role. Given the discriminative functions of the tokens it may not be surprising, then, that larger tokens produced larger effects given their greater salience.
Another type of complex sequence schedule, similar to token reinforcement schedules in some respects, involves the presentation of stimuli that are presented briefly after the completion of some simple schedule: second-order schedules of brief stimulus presentation. As with token-reinforcement procedures, the completion of each schedule segment, or unit schedule, produces a discriminable stimulus change (e.g., a flash of light, a tone) and contributes to a higher-order schedule by which primary reinforcement is presented. Some research has shown that brief stimuli can serve a discriminative role, organizing behavior with respect to the temporal proximity of primary reinforcement (Kelleher, 1966). Other research has shown that the effects of brief-stimulus presentation may vary depending on the value of the schedule of brief-stimulus presentation and the primary reinforcement schedule.

Kelleher (1966) investigated whether a brief stimulus presented after completion of an FI would be sufficient to maintain pigeons’ responding under an extended second-order schedule. Pigeons were exposed to an FR 30 (FI 2-min) or an FR 15 (FI 4-min) schedule with a brief stimulus presentation (white key light flash) occurring after completion of each FI. Kelleher notates second-order schedules by listing the schedule of stimulus presentations required for completion first and the schedule of stimulus presentation in parentheses. Thus, FR 30 (FI 2-min) denotes a schedule in which a stimulus is presented after completion of every FI 2-min and that requires 30 FI 2-min completions before primary reinforcement is presented. Performance under each
condition in this experiment was compared to performance under a tandem schedule with similar contingencies but the absence of brief-stimulus presentations. Responding in both brief-stimulus conditions was characterized by low rates of responding early in a cycle increasing as a function of proximity to primary reinforcement. Further, within a given FI, response rates had a scalloped pattern with pausing after the presentation of a brief stimulus and with response rates increasing as a function of temporal proximity to the next brief stimulus. Responding under the two brief-stimulus conditions was thus organized with respect to both the FI brief-stimulus schedule and the FR primary-reinforcement schedule. Responding under the tandem-control conditions was markedly different than under the brief-stimulus conditions in that response rates were lower and relatively constant throughout the cycle, with a slight increase as primary reinforcement approached. Kelleher concluded that the brief-stimulus presentations served as conditioned reinforcers, facilitating performance when compared to tandem-control conditions.

Lee and Gollub (1971) exposed pigeons to a procedure that arranged for primary reinforcement delivery after 256 responses. A briefly-presented stimulus (0.5 s green light) was presented after a fixed number of responses, varied from 2 to 256 across several conditions. They found an inverted U-shaped function relating response rates to the size of the FR brief-stimulus schedule, with the highest response rates generally occurring under the FR 64 and 128 brief-stimulus presentation conditions. The high rates of responding under the middle brief-stimulus presentation values may be indicative of a conditioned reinforcement function. Evidence for this account is provided by the response patterning with respect to the briefly-presented stimuli, patterning similar to that
seen under simple schedules. Lower response rates seen under the small FR brief-stimulus schedules were thought to indicate a discriminative function, with low rates at the beginning of the cycle due to the pairing of early brief-stimulus presentations with long delays to reinforcement.

The present experiment sought to connect findings from research on second-order schedules of brief-stimulus presentation with token reinforcement schedules. The features of token-reinforcement schedules that differ from a brief-stimulus schedule are (a) the duration of stimulus presentation, (b) the correlation between stimulus number and primary-reinforcement magnitude, and (c) the correlation between number of stimuli illuminated and temporal proximity to exchange (Bullock & Hackenberg, 2006; Foster et al., 2001). For example, in token reinforcement schedules, the number tokens earned is inversely proportional to the number of responses remaining, and directly proportional to the number of reinforcers available during the exchange period. To more precisely evaluate the correlation between the number of tokens and both response requirements and temporal proximity to exchange, the present experiment arranged for comparisons between token schedules and several variants of brief-stimulus schedule configurations. As in Experiment 1, a multiple schedule was used to allow for within-session comparisons of response rates and patterning under the different schedule arrangements.

**Method**

**Subjects**

Four White Carneau pigeons (*Columba livia*), numbered 47, 83, 832, and 999, served as subjects. All had previously served in Experiment 1: Pigeons 47 and 83 in the large-token box and 832 and 999 in the small-token box.
Apparatus

The chamber with the larger tokens was the only one used in the experiment (i.e., the standard three-key pigeon chamber with a row of 12 evenly-spaced stimulus lights from Experiment 1).

Procedure

The procedure was similar to that of Experiment 1 with the exceptions that the exchange-production schedule was held constant at FR 4, both the left and right keys were used, and in place of the tandem component, a brief-stimulus schedule was used. As in Experiment 1, sessions were comprised of a 2-component multiple-schedule with 2 exposures to each component per session. Component remained in effect for 16, 1.5-s food deliveries, and occurred in a pseudo-random order. Following the completion of a component, a 30 s blackout (intercomponent interval) occurred. Sessions began with the illumination of the white houselight and either the left or right key (either green or yellow depending on component type). Conditions lasted for at least 14 sessions and until response rates were deemed stable via visual inspection.

A component began with the illumination of the left or right key, with the position of the key for a component type remaining constant throughout a condition. For components with responses recorded on the left key, tokens where illuminated left to right, while for components in which responses were recorded on the right key, tokens were illuminated right to left. A token schedule was used for one component of the multiple schedule and one of 3 types of brief stimulus schedules for the other. For the brief-stimulus arrangement, a token or tokens were illuminated briefly (0.5 s presentation), accompanied by a tone (0.1 s presentation) following the completion of each FR 50 on the token-production key. Upon the completion of a brief-stimulus
component cycle four tokens illuminated and the exchange period began. The exchange periods were otherwise identical across component types. Table 3-1 lists the order of conditions and number of sessions per condition. Key colors were reversed under replications.

Table 3-1. Order of conditions and number of sessions per condition for Experiment 2. Number of sessions per condition is listed in parentheses.

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>47</th>
<th>83</th>
<th>832</th>
<th>999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Token (30)</td>
<td>Token (31)</td>
<td>Token (18)</td>
<td>Token (43)</td>
<td></td>
</tr>
<tr>
<td>BMS (52)</td>
<td>BMS (44)</td>
<td>BMS (38)</td>
<td>BMS (55)</td>
<td></td>
</tr>
<tr>
<td>BAS (14)</td>
<td>BAS (40)</td>
<td>BAS (34)</td>
<td>BAS (31)</td>
<td></td>
</tr>
<tr>
<td>BFS (34)</td>
<td>BFS (31)</td>
<td>BFS (70)</td>
<td>BFS (22)</td>
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</tr>
<tr>
<td>BMS (48)</td>
<td>BMS (52)</td>
<td>BMS (24)</td>
<td>BMS (18)</td>
<td></td>
</tr>
</tbody>
</table>

Initially, pigeons were exposed to a condition with token reinforcement schedules in both components, followed by variations of a brief stimulus schedule in one component. One of three types of brief-stimulus components alternated with the token component. In one condition, a brief-moving stimulus (BMS) configuration was used, in which only 1 token flashed at the end of each FR 50 but changed position (left to right or right to left) depending on the number of segments completed. Thus position but not number of tokens was correlated with temporal proximity to exchange. In another condition, a brief-added stimulus (BAS) configuration was used, in which tokens illuminated in the same manner as the token component, but only remained illuminated briefly. Both position of the stimuli and number of stimuli illuminated was correlated with temporal proximity to food delivery. For a third type of condition, a brief-full
stimulus (BFS) configuration was used in which 4 tokens flashed after every 50 responses. In this configuration, no feature of the stimulus itself, other than the number of times it was illuminated, was correlated with food delivery.

**Results**

Figures 3-1 and 3-2 show for each pigeon running response rates (response rates factoring out pre-ratio pausing) and pre-ratio pauses, respectively, for each condition in Experiment 2. For each condition the filled bars represent performance under token-reinforcement schedule components while the open bars show performance under the brief-stimulus components.

No systematic differences were evident with respect to response rates or pre-ratio pausing between the three brief-stimulus schedule variants examined. Response rates under the brief-stimulus components in two cases were higher, and pre-ratio pausing lower, than those maintained under the token components. For Pigeon 832, differences between the brief-stimulus components and token components were not pronounced, whereas for 999 response rates were generally higher under the token components. Further, for Pigeons 83 and 47, differences in the response rates between the token and brief-stimulus components were due mainly to differences in the early links of a cycle.
Figure 3-1. Mean responses per minute (not including pre-ratio pause) and standard deviations from the last 5 sessions of a condition. Filled bars represent data from the token component while open bars represent data from the component varied across conditions.
Figure 3-2. Mean pre-ratio pause and standard deviations from the last 5 sessions of a condition. Filled bars represent data from the token component while open bars represent data from the component varied across conditions.

Figures 3-3 and 3-4 show response rates and pre-ratio pausing for token and brief-stimulus components as a function of segment (position in the exchange-production cycle). In general, responding in brief-stimulus components resembled that of the tandem components from Experiment 1: Low initial-link response rates gave way to higher, constant rates in the later links. Performance under the token components also resembled that of token performance in Experiment 1 in that response rates gradually increased as a function of the number of tokens earned. Further, in most cases for both the token and
tandem components, pre-ratio pausing was longest for the initial segments and gave way
to small pauses for subsequent segments.

Figure 3-3. Mean responses per minute (not including pre-ratio pause) plotted as a
function of token production or brief-stimulus segment from the last 5
sessions of a condition. Open symbols represent data from brief-stimulus
components, closed from token components, solid lines represent original
exposures, and dashed lines represent replications.
Figure 3-4. Mean pre-ratio pausing plotted as a function of token production or brief-stimulus segment from the last 5 sessions of a condition. Open symbols represent data from brief-stimulus components, closed from token components, solid lines represent original exposures, and dashed lines represent replications.

**Discussion**

Several brief-stimulus configurations were arranged to incorporate features of token-reinforcement schedules. However, neither a standard-brief stimulus schedule, nor one that varied stimulus position or magnitude as a function of proximity to reinforcement, produced behavior markedly different from what was found in the tandem schedules from the previous experiment. For two subjects, response rates under brief-stimulus components were higher than those under token components.

The similarities between the brief-stimulus and tandem components, and the lack of a difference between the variants of the brief-stimulus configurations, may be due to both
the values of the token-production and exchange schedules and the duration of stimulus presentations. Results from Lee and Gollub (1971) indicated that the effects of brief-stimulus presentations vary depending on the value of the stimulus-production schedule. As mentioned earlier, Lee and Gollub (1971) used a procedure in which the number of responses required to produce food remained constant at 256, and across conditions the FR production value of the brief-stimulus was varied. They obtained the highest rates of responding when either 2 or 4 brief stimuli occurred per food presentation. The present procedure had 4 brief-stimulus presentations per primary reinforcement period and it may be that this particular value, similar to Lee and Gollub (1971), produced a high rate of responding. In the absence of parametric variation it is difficult to determine if under other schedule values performance on the present brief-stimulus arrangements would produce behavior similar to that under the token-reinforcement component. This argument may be extended to account for the lack of effects under the different variations of brief-stimulus schedules presently employed. It may be that under different brief-stimulus presentation schedule values differences in performance would be observed.

The present findings also are suggestive that the duration of the stimulus presentation is an important variable, perhaps enhancing the discriminative function of tokens by more clearly demarcating each segment. Although the only difference between the brief-added stimulus components and the token components was the duration of stimulus presentation, in some cases the two components had considerably different response rates and patterning. It may be that the continuous display of stimuli makes more salient the temporal correlation between number of tokens and delay to and amount of food available during exchange. Parametric manipulation of stimulus duration in the
context of several token-production and exchange schedules would be needed, however, to more adequately test this possibility.
Similarities between token-reinforcement and extended-chained procedures have been noted several times by previous researchers (Gollub, 1970; Kelleher and Gollub, 1962). Indeed, the long pauses at the beginning and response patterns throughout an extended-chained cycle are similar to those seen in the token components from the first 2 experiments and in other token-reinforcement schedules with FR token-production and exchange schedules (Bullock and Hackenberg, 2006; Foster et al., 2001; Kelleher, 1958; Webbe & Malagodi, 1978). Two methods for more systematically investigating similarities between token-reinforcement and chained schedules would be to (a), make token-reinforcement schedules more similar to chained schedules, and (b), replicate with token-reinforcement schedules previously investigated variations in chained schedules. In particular, the manner of presentation and order of stimuli in chained schedules have been modified to more precisely determine the function of the stimuli demarcating a given link—a procedure that could be readily adapted to token-reinforcement schedules.

Kelleher and Fry (1962) examined pigeons’ responding over a series of conditions involving a traditional-chained schedule, a modified-chained schedule in which the stimuli denoting each link varied from cycle to cycle, and a tandem control. The chained schedule was comprised of three sequential FI schedules. It was found that, following a pre-ratio pause, responding occurred at a high, steady rate under the tandem schedule. Under the traditional-chained schedule, responding was characterized by a long pre-ratio pause and low response rates in the first link, followed by progressively increasing rates.
in the second and third links. When compared to the first two links of the traditional-chained schedule, response rates under the variable-chained schedule were higher and pre-ratio pauses lower. Unlike performance under the tandem schedule, response rates were positively accelerated in the chained-schedule conditions, a finding indicative of a discriminative function. Although the present experiment used FR rather than FI schedules, Kelleher and Fry’s (1962) manipulations are readily adaptable to token-reinforcement procedures, and may be similarly revealing of token-stimulus functions.

In another study aimed at discovering stimulus function in chained schedules, Byrd (1971) examined pigeons’ responding when the same stimulus was presented in more than one link of a chain cycle. Pigeons responded on a chained schedule with each link comprised of a 1 min FI and with the number of links varied across conditions (3, 5, 7, and 8). During most conditions the same stimulus was used for the odd numbered links and a distinct stimulus for the even. For instance, under the condition with 7 links, the same stimulus was used for links 1, 3, 5, and 7. The one exception was the 8-link condition, in which the same stimulus was used for the even numbered links. A 7-link control condition was also examined, identical to those previously described with the exception that a distinct stimulus was used for link 7. In keeping with other findings concerning extended-chained schedules, Byrd found that response rates tended to increase from almost zero in link 1 to high rates of responding as a function of temporal proximity to food. However, under conditions with 5 and 7 links, response rates under the later links with the same color stimulus were higher compared to the following distinct stimulus link, despite closer temporal proximity to food of these links. Under the 7-link chain condition with a distinct stimulus for the terminal link, response rates were
lower when compared to the previous 7-link condition. Further, under the 8-link condition response rates under link 1 were still extremely low, but increased under the most temporally distant same color link, link 2.

Byrd interpreted these effects as showing that the discriminative properties of stimuli in chained schedules are important determinants of response rate. The response rate increasing effect of having several previous links share the same stimulus as the terminal link may be indicative of a conditioned reinforcing effect. However, they suggest that response-rate increases in chained schedules cannot be unambiguously interpreted as due to conditioned reinforcement. If conditioned reinforcement were the sole factor in determining performance on this procedure, one would expect that response rates in link 1 of the 8 link condition would be higher than those of link 1 from the 7-link condition, due to the production of the stimulus also associated with the terminal link.

Both the results of Kelleher and Fry (1962) and Byrd (1971) emphasize the importance of the discriminative properties of stimuli in extended-chain schedules. In a similar vein, the present research manipulated several features of the stimulus-food relations in token reinforcement schedules to assess the stimulus functions of the tokens. Initially the token reinforcement schedule was altered such that it was more procedurally similar to a standard extended-chained schedule. Tokens were presented at the completion of each FR link, but only one reinforcer was available during exchange. If similar mechanisms influence performance on token reinforcement and extended-chain schedules then one would expect to see little difference between performance under a standard-token reinforcement procedure and one that is more like an extended chain. In a second condition, the standard token-reinforcement schedule was compared to one
altered such that the stimulus events preceding an exchange occurred in the reverse order. Reversing the order of stimuli results in perhaps a less distinct stimulus at the beginning of a cycle, 4 tokens present, than under the standard token contingencies, the complete absence of tokens. As in Byrd (1971), the stimuli immediately preceding primary reinforcement may gain more of a conditioned reinforcing effect than those occurring earlier in an extended chain cycle, a finding that may also be true in token-reinforcement schedules. Lastly, a condition was arranged in which the contingency between number of tokens and temporal proximity to an exchange was weakened. In this condition tokens were produced according to a VR schedule while exchanges occurred after 200 responses, irrespective of how many tokens had been produced. Similar to the effects of the variable-order stimulus condition from Kelleher and Fry (1962), one would expect that as the contingency between a number of tokens and proximity to exchange is degraded, performance would come to more closely resemble those from the tandem components described in Experiment 1.

**Method**

**Subjects and Apparatus**

The subjects and apparatus were the same as in Experiment 2.

**Procedure**

Similar to Experiment 2, a 2-component multiple schedule was used in Experiment 3. Each component type occurred twice per session. In one component, a token-reinforcement schedule was in place while the other component consisted of a variant of a token schedule. In both components, an exchange period occurred after 200 responses; in the token components, tokens were produced after every 50 responses and exchanges after every 4 tokens (FR 4 [50]). Components were ordered pseudo-randomly, with
components remaining in effect for four exchange cycles. A 30-s blackout followed each component. Sessions began with the illumination of the white houselight and the left or right side key (either green or yellow depending on component type). Conditions were in effect for a minimum of 14 sessions and response rates were deemed stable across the last 5 sessions via visual inspection.

The token-variant component involved 3 variations on the standard token schedule: reinforcement magnitude, order of token delivery, and schedule of token delivery. In the first, a one-reinforcer token schedule (1 Rein) was in place. This variant is analogous to standard-chained schedules (in which a single reinforcer is available at the end of the terminal link) but with all other features identical to a standard token-reinforcement schedule. That is, identical to the token-reinforcement component, tokens were produced according to an FR 50 and exchange periods occurred after 4 tokens were produced. However, the first exchange response darkened all tokens and produced just one 1.5 s food delivery.

Another variant, reverse-order token schedule (reverse), was in place for some conditions. This variant was identical to a standard token-reinforcement schedule with the exception that a token-production cycle began with 4 tokens and every 50 responses extinguished one. Thus the removal of tokens, rather than the presentation, was correlated with temporal proximity to exchange. Following the removal of the last token, 4 tokens were illuminated and an exchange period began.

A third variant, broken-contingency token schedule (VR), was also in place for some conditions. Under this variant, responses produced tokens under a VR 50 schedule (up to a maximum of 12). The number of tokens produced, however, was unrelated to
exchange, with exchanges occurring after 200 responses. Under these components it was possible to enter an exchange with fewer or greater than 4 tokens. However, during the exchange, 4 reinforcers were available, with each exchange response darkening a token. If more than 4 tokens had been produced, then additional center key responses were required to darken the remainder before another token-production cycle began. If fewer than 4 tokens had been produced, responses on the center key simply continued to produce food until 4 reinforcers had been obtained. The uncompleted VR value at the end of a cycle was simply used as the first for the next cycle. Table 4-1 lists the order of conditions and number of sessions per condition.

Table 4-1. Order of conditions and number of sessions per condition for Experiment 3. Number of sessions per condition is listed in parentheses.

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>47</th>
<th>83</th>
<th>832</th>
<th>999</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Rein. (47)</td>
<td>1 Rein. (24)</td>
<td>1 Rein. (17)</td>
<td>1 Rein. (28)</td>
<td></td>
</tr>
<tr>
<td>Reverse (26)</td>
<td>Reverse (17)</td>
<td>Reverse (38)</td>
<td>Reverse (11)</td>
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</tr>
<tr>
<td>VR (35)</td>
<td>VR (23)</td>
<td>VR (30)</td>
<td>VR (26)</td>
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</tbody>
</table>

**Results**

Figures 4-1 and 4-2 show for each pigeon responses per minute and pre-ratio pauses, respectively, for both component types across conditions. The filled bars represent performance under the token-reinforcement schedule while the open bars show chained-schedule performance. For all subjects except 83, response rates were lower and pre-ratio pauses longer in the one-reinforcer than in the token component. For 3 out of 4 subjects under the reversed order and broken contingency conditions, this relationship was reversed, with response rates lower and pausing longer in the token component. The lone exception in these latter conditions was Pigeon 999, for whom response rates
remained higher in the token component for all conditions in this experiment. Even for this subject, however, response rates were slightly higher under the broken-contingency and reversed-order components than under the one-reinforcer components.

Figure 4-1. Mean responses per minute (not including pre-ratio pause) and standard deviations from the last 5 sessions of a condition. Filled bars represent data from the token component while open bars represent data from the other (no-token) component.
Figure 4-2. Mean pre-ratio pause and standard deviations from the last 5 sessions of a condition. Filled bars represent data from the token component while open bars represent data from the other (non-token) component.

Figures 4-3 and 4-4 show response rates and pre-ratio pausing for each 50-response segment, respectively, for both components across conditions. Filled circles represent responding under the token-reinforcement components and open circles under the components with the chained-schedule variants. For all pigeons under the one-reinforcer contingency components, and for 2 out of 4 subjects under the opposing token components, response patterning was graded with response rates increasing across segments. Interestingly, for Pigeon 999 and to some extent for Pigeon 832, response rates
were fairly constant throughout the token cycle for this condition. Under the reversed-order and broken-contingency components, response rates early in the cycle increased compared to those in the opposing token schedule for all subjects except Pigeon 999. Response patterning across the cycle was similar for both the reversed-order and broken-contingency components in that in most cases response rates were low in the initial segment and remained somewhat constant (Pigeons 832 and 999) or gradually increased (Pigeons 47 and 83). Response rates in the opposing token components, however, were marked by a more accelerated function than the other component in 6 of 8 cases. Similar to the previous experiments, pre-ratio pausing for both components was characterized by long pauses in the initial segment giving way to short, constant pauses thereafter.

Figure 4-3. Mean responses per minute (not including pre-ratio pause) plotted as a function of token production or 50 response segments from the last 5 sessions of a condition. Open symbols represent data from token variant components while closed symbols represent data from token components.
The primary findings from this experiment were that, relative to rates in the token-reinforcement schedule, response rates were lower under the chain-like procedure and higher under the broken-contingency and reversed-order procedure. Further, as shown in Figure 4-3, response patterning reflected, to some degree, manner of token presentation.
The one-reinforcer contingency produced lower response rates, compared to the opposing token component, a joint product of longer pre-ratio pauses and lower response rates early in a cycle. Data from the one-reinforcer token schedule indicated that response rates were sensitive to reinforcer magnitude, with rates consistently higher in the token component (4 food deliveries) than in the chained component (1 food delivery). This could be due to the greater reinforcer magnitude in the token component or to the correlation between number of tokens and reinforcer magnitude in that component. That response rates in the initial links of the reverse-order condition remained low relative to later links suggest that low response rates in early links are not simply due to the absence of tokens. These data speak to the importance of the correlation of the tokens with temporal proximity to food. That response rates increased in the broken-contingency component relative to the token component for 3 out of 4 subjects suggests that the correlation between number of tokens and proximity to exchange is important.

Although there was a difference in overall response rates between the chain-like and token reinforcement schedules, the qualitative patterns of responding were similar, with response rates increasing across a cycle as tokens accumulated. This finding provides some support for the notion that the discriminative properties of chained and token-reinforcement schedules are similar. The overall increases in response rates under the broken-contingency components are similar to those of the variable-order condition from Kelleher and Fry (1962). Results from both experiments suggest that the presence or absence of a given number of tokens or type of stimulus is arbitrary: what matters is the temporal relation between the tokens and food.
In token-reinforcement schedules the tokens have been shown to have several functions, including conditioned reinforcers (Kelleher and Gollub, 1962) and discriminative stimuli (Bullock and Hackenberg, 2006). Research has shown that pigeons’ key pecking can be generated irrespective of operant contingencies via stimulus-food relations (Brown & Jenkins, 1968). The typical procedure for generating such autoshaped, or automaintained, behavior is to repeatedly present a keylight, followed by response-independent food delivery (Brown and Jenkins, 1968). Some of the conditions under which such autoshaped keypecking has been generated and maintained are similar to token reinforcement schedules. For example, autoshaped responding can be generated under conditions in which distinct stimuli are presented successively, temporally correlated with food presentation (Ricci, 1973).

Ricci (1973) examined pigeons’ autoshaped key pecking under several stimulus arrangements. In some conditions subjects were exposed to contingencies in which a sequence of 4 colors was presented for 30 s each, with the terminal stimulus followed by food reinforcement. Performance was then compared to that generated under a similar procedure except that just one stimulus was presented for the entire 120 s prior to food delivery. Response distributions under the 4-color conditions were graded, with response probability increasing as a function of the temporal proximity of that stimulus to reinforcement. By contrast, responding under the 1-color conditions was much more uniform throughout the 120 s interval. It was suggested that such autoshaping procedures
are similar to chained schedules in that both involve sequential arrangements of stimuli temporally related to food.

It is possible that responding on schedules of token reinforcement may be maintained simply by the presentation of tokens, with the number of tokens presented correlated with temporal proximity to food. The present experiment was designed to investigate this possibility. In one component of a multiple schedule tokens were presented response-independently, yoked to their temporal occurrence in the immediately prior token reinforcement component. Under simple schedules, response-independent reinforcement breaks the dependency between responding and food production and results in lower response rates (Lattal, 1972). If the tokens served as conditioned reinforcers then presenting them response independently should result in a substantial decrease or elimination of response rates. On the other hand, if tokens served an eliciting function, in the manner of serial autoshaping, one would expect some maintenance of responding. To examine whether the presence versus absence of the tokens was an important determinant of responding in the yoked component, the tokens were removed from the yoked component in some conditions, while exchanges remained yoked to their temporal occurrence in the preceding token component. These conditions were designed to determine to what degree responding maintained under token-reinforcement schedules is a product of the temporal relations between tokens and food, apart from the contingent production of tokens. To examine the possibility that induction from the token schedule could account for responding in the yoked components, other conditions held constant the key color in both component types. If induction was a determinant of responding in the
yoked component one would expect that by making the two components more similar response rates in the two components would converge.

**Method**

**Subjects and Apparatus**

The subjects and apparatus were the same as in Experiments 2 and 3.

**Procedure**

Similar to the other experiments reported, a 2-component multiple schedule was used in Experiment 4 with a token-reinforcement component and a yoked component. Each component occurred twice and lasted for 4 exchange cycles. A 30-s blackout followed each component. Sessions began with the illumination of the white houselight and side key associated with the token component (either green or yellow). In the token component tokens were produced every 50 responses and exchanges after every 4 tokens (FR 4 [50]). In the yoked component, tokens and exchange periods were presented response independently, yoked to the times they occurred in the preceding token component. The token components always occurred first and third, the yoked component second and fourth.

Two other conditions consisted of (a) holding the token-production key color constant across both components (Yoked Color-Same, or CS), and (b) removing the tokens entirely from the token-production cycle of the yoked component (Yoked No Token, or NT). In this latter condition, 4 tokens illuminated immediately prior to the exchange period while the number of reinforcer deliveries (4) and delays to the exchange period were equal to those in the token component. Conditions were in effect for a minimum of 14 sessions and until response rates were deemed stable across the last 5
sessions via visual inspection. Table 5-1 lists the order of conditions and number of sessions per conditions

Table 5-1. Order of conditions and number of sessions per condition for Experiment 4. Number of sessions per condition is listed in parentheses.

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>47</th>
<th>83</th>
<th>832</th>
<th>999</th>
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</thead>
<tbody>
<tr>
<td>Yoked</td>
<td>34</td>
<td>Yoked</td>
<td>35</td>
<td>Yoked</td>
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<tr>
<td>Yoked NT</td>
<td>14</td>
<td>Yoked NT</td>
<td>15</td>
<td>Yoked NT</td>
</tr>
<tr>
<td>Yoked</td>
<td>16</td>
<td>Yoked</td>
<td>20</td>
<td>Yoked</td>
</tr>
<tr>
<td>Yoked CS</td>
<td>17</td>
<td>Yoked CS</td>
<td>30</td>
<td>Yoked CS</td>
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</table>

Results

Figures 5-1 and 5-2 show running response rates (response rates factoring out pre-ratio pausing) and pausing for each pigeon, respectively, across the final 5 sessions in each condition. Filled bars show performance from the token components while open bars show performance from the yoked components. Response rates for all conditions in the standard-token component were higher than in any of the yoked-component variations. Pausing was also generally greater in the yoked than in the token components. Response rates in the standard-yoked components were lower than in to the opposing token components, but never reached zero. Under the no-token (NT) yoked condition, however, responding was almost completely eliminated. In the yoked component with the token-production key color the same as the opposing token component (CS), response rates were either comparable to, or lower than, those in the standard yoked-token conditions for 3 out of 4 pigeons.
Figure 5-1. Mean responses per minute (not including pre-ratio pause) and standard deviations from the last 5 sessions of a condition. Filled bars represent data from the token component while open bars represent data from the yoked component.
Figures 5-2, 5-3, and 5-4 show response rates and pausing for each component type across successive segments in the exchange cycle. Segments consisted of either 50 responses (token component) or the equivalent time periods (yoked component). Response patterning under the token components was graded, increasing as a function of the number of tokens earned and proximity to food. Under the standard token-yoked conditions, responding within a cycle was characterized by extremely low rates for the first one or two segments followed by an increase, resulting in rates close to those of the comparable token component for segments 3 and 4. For all pigeons under the no-token...
yoked components response rates were equally low for all 4 segments. Segment pauses, (Figure 5-4) also corresponded to this pattern, with long pauses in the early links of a cycle becoming shorter with increasing numbers of tokens illuminated. (Under the yoked conditions pausing sometimes exceeded the period of time before the first token illuminated. In such cases, the link 1 pause was set to the time period before token presentation. The mean pre-ratio pauses, shown in Figure 5-2, however, were based on the actual time prior to a response, irrespective of token illumination.)

Figure 5-3. Mean responses per minute (not including pre-ratio pause) plotted as a function of token production or yoked token-production segment from the last 5 sessions of a condition. For no-token yoked components the segment data are organized around when the token would have occurred. Open symbols represent data from yoked components, closed from token components, solid lines represent original exposures, and dashed lines represent replications.
Figure 5-4. Mean pre-ratio pausing plotted as a function of token production or yoked token-production segment from the last 5 sessions of a condition. For no-token yoked components the segment data are organized around when the token would have occurred. Open symbols represent data from yoked components, closed from token components, solid lines represent original exposures, and dashed lines represent replications.

Figure 5-5 shows the obtained delays between the last response of a segment and the illumination of a token for that segment, across successive segments within an exchange cycle. For cases in which a response did not occur within a given segment, the duration of the segment was used as the delay. The response-token delays varied both across subjects and across segments within an exchange cycle for individual subjects.
For Pigeon 999, the mean response-token delays were generally quite long, rarely less than 10 s. For the other 3 pigeons, response-token delays were generally high in the early segments, but became shorter in the later links when response rates were high.

![Graph showing response-token delays for different pigeons and token conditions.](image)

Figure 5-5. Mean time between the last response of a segment and the token production plotted as a function of yoked token-production segment from the last 5 sessions of a condition.

**Discussion**

Response rates in the yoked components were lower than in the token components, suggesting a role for the dependency between responding and token production (i.e., a reinforcing function). In the yoked components, the presence of tokens maintained
responding at much higher levels than when they were absent. Within a yoked-token component, response rates increased as a function of the temporal proximity to food in much the same way that they did under response-dependent token production. This finding, similar to that reported by Ricci (1973), suggests a discriminative and/or eliciting role for the tokens. When the key color was held constant, response rates were equal to or slightly lower than the regular-yoked components, indicating that induction from the token component does not account entirely for responding in the yoked component. However, because of the previous history of reinforcement on token-reinforcement schedules statements concerning the degree to which the discriminative versus eliciting properties of the stimuli control behavior are limited.

Figure 5-5 shows that an adventitious contingency does not explain the present results entirely. Response rates increased in a graded fashion, as a function of the number of tokens earned (see Figure 5-3). There existed a considerable delay between responding and the illumination of the first and second tokens, and relatively short delays between responding and the presentation of the third and fourth tokens. If an adventitious contingency had existed with respect to responding and production of the later tokens, one would expect that responding would be entirely absent prior to the first two token deliveries, rather than the observed graded functions that were found.
CHAPTER 6
GENERAL DISCUSSION

The objective of this series of experiments was to explore systematically the stimulus functions of tokens in token-reinforcement schedules. Performance under schedules of token reinforcement was compared to that under tandem schedules and to that under several token-like schedules, all with equivalent response requirements. Experiment 1 compared token schedules to equivalent tandem schedules and found that response rates under token-reinforcement schedules were lower than under tandem schedules, with response patterning suggesting a discriminative function of the tokens. Experiment 2 compared token schedules to several schedules of briefly-presented token presentation, and found that response rates under token-reinforcement schedules were in some cases lower than under variants of the briefly-presented stimulus schedules. Rates and patterns in the latter were comparable to the tandem components in Experiment 1, suggesting that the continuous display of tokens contributes to their discriminative effects. Experiment 3 compared token schedules to extended chained schedules, and found that response rates under token-reinforcement schedules were lower than under comparable chained schedules when the correlation between token display and temporal proximity to exchange periods was altered. Only when compared to standard-chained schedule, with a single reinforcer at the end of the chain, were response rates higher in token schedules, indicating sensitivity to reinforcement magnitude with stimulus conditions held constant. Experiment 4 compared token schedules to schedules of response-independent token presentation to assess the reinforcing and potential eliciting
functions of the tokens. Response rates were reduced under the response-independent schedules, suggesting a reinforcing function, but they were not eliminated, suggesting an eliciting function. Taken together, the results suggest that tokens serve important stimulus functions in token reinforcement schedules, and that the specific function, or functions, depend on the contingencies in which they are embedded.

The results of the Experiment 1 correspond to those seen in prior research with token schedules (Bullock & Hackenberg, 2006; Foster et al., 2001), added-stimulus schedules (Zimmerman & Ferster, 1964), and extended-chained schedules (Jwaidah, 1973). Decreases in response rates in the present experiment as a function of increasing the exchange-schedule requirements is consistent with previous token-reinforcement schedule findings using FR exchange schedules (Bullock and Hackenberg, 2006; Foster et al., 2001). The graded pattern of responding found under token-reinforcement schedules in the present research correspond to both previous token-reinforcement research and to the effects off adding incremental stimulus changes reported by Zimmerman and Ferster (1964). Higher rates of responding in components with tandem schedules, when compared to components with token schedules, reported in Experiment 1, correspond to similar manipulations with extended chained schedules (Jwaidah, 1973).

Experiment 2 showed that briefly presenting tokens attenuated their discriminative function, irrespective of whether their position and number was correlated with responses/temporal proximity to reinforcement. The lack of a discernable effect between the brief-stimulus conditions, combined with the differences for some pigeons between the brief-stimulus and token components, points to the importance of token display duration. Briefly presenting the tokens may have decreased their salience and
thus disrupted the discriminative properties of the tokens, a result that was perhaps similar to the effects of varying token size in Experiment 1. In other words, the results of Experiment 2 suggest that the functions of tokens in second-order schedules are related to how long they demarcate the completion of each segment.

The results of Experiment 3 showed that the discriminative properties of tokens in token-reinforcement schedules are similar in several respects to stimuli in chained schedules. As mentioned earlier, Kelleher and Fry (1962) found that randomizing the order of stimuli delineating the links in an extended chain schedule increased response rates relative to a standard extended-chained schedule. A similar result was found by Kelleher (1958) when chimpanzee’s pre-ratio pauses decreased as a result of the non-contingent delivery of a large group of tokens prior to the start of a session. In Experiment 3 of the present study, the condition that involved use of a VR schedule of token production that operated independently of the FR 200 exchange-production schedule was analogous to randomizing the stimuli in Kelleher and Fry (1962). The use of a VR token-production schedule in the present research and the procedures used in Kelleher and Fry (1962) and Kelleher (1958) were all similar in that degrading the correlation between tokens and temporal proximity to food resulted in decreased pre-ratio pausing or increased rate of responding.

Experiment 4 was designed to assess the conditioned reinforcing and eliciting functions of the tokens by removing the dependency between responding and token presentation. In this experiment responding under a standard token-reinforcement schedule was compared to that under a procedure where tokens were delivered response independently, yoked to their temporal occurrence in the preceding standard token.
schedule component. If the tokens served as conditioned reinforcers one would expect that response rates would either substantially decrease or completely cease, as response-independent token delivery would break the contingency between responding and token production. However, if the tokens had an eliciting function, responding should continue, as response-independent token delivery would not alter the token-food correlation. Responding was reduced in yoked conditions, suggesting a reinforcing function, but it was not eliminated, suggesting an eliciting function. The latter result is consistent with those reported by Ricci (1973), described earlier, in which the probability of a response in the presence of a given stimuli increased as a function of temporal proximity to food. A similar relationship was found in Experiment 4, suggesting that tokens may serve to elicit responding in addition to other functions. Similar to the common discriminative properties of stimuli in token reinforcement and chained schedules, research has shown that stimuli in chain schedules also have an eliciting function.

In support of this, Dougherty and Lewis (1991) used an omission procedure to investigate further the degree to which extended-chained schedule stimuli have eliciting functions. An omission procedure is one in which the occurrence of a response prevents the delivery of reinforcement. Thus, if responding is maintained by operant contingencies, one would expect an omission procedure to eliminate responding. Conversely, if responding is due to the stimulus-food relations and is independent of operant contingencies, then responding should still occur. Pigeons were exposed to 3 conditions, 2 with an omission contingency and one with a standard chain. In the first, a 2-link chain was in effect, with each link lasting for 60 s and with transition occurring response independently. Responses in the first link terminated the chain and began an
inter-trial interval (ITI). The second condition was similar to the first except that an FI 60 s schedule was in effect for both links. If responses occurred before 60 s had elapsed in the first link then the chain terminated and the ITI began. The third condition was a standard chain with an FI 60 s in both components. That responding occurred in the initial link of the first two conditions (with an omission procedure), in spite of resulting in a lower rate of reinforcement, suggests that the stimuli in these procedures had an eliciting function. Thus, consistent with the results of Ricci (1973) and the present experiment, chain-schedule stimuli also have eliciting functions.

Taken together, the results of the experiments presented here suggest that stimuli in token-reinforcement procedures can have a combination of functions. Experiment 1 showed that response rates are lower under token reinforcement schedules when compared to equivalent tandem schedules. This finding, along with a more graded pattern of responding found under the token-reinforcement schedules suggests that tokens have a discriminative function. The results of Experiment 2 suggest that the duration of token presentation is an important determinant of the discriminative functions of tokens. Experiment 3 showed that changing the token production schedule to a VR increased response rates, a finding that again suggests a discriminative function. Results from Experiment 4 showed that response rates continue in the absence of a contingency between responding and token production, a finding that suggests tokens may have a response eliciting function. Further, higher response rates in Experiment 4 under the standard token-reinforcement schedule than under the yoked schedule speaks to the role of a dependency between responses and tokens, and may be indicative of a conditioned reinforcing function. Thus, the present research suggests that the functions of stimuli in
token reinforcement procedure have eliciting, discriminative, and reinforcing properties and that the particular function depends on the contingencies in place.

While the present research shows that the tokens have several functions, many dimensions of a token reinforcement procedure have yet to be investigated. Research that varies the length of presentation of a brief-stimulus from very short to almost the entire segment period would allow for a more precise understanding how stimulus function varies as the schedules shift from more brief-stimulus-like to more token- or chain-like. Manipulations of stimulus durations are particularly suited to experimental preparations that allow for controlled presentations, as opposed to manipulable tokens used in some of the studies discussed earlier.

Second, most prior research has conducted comparisons of the various component types under only 1 token production and exchange value. Bullock and Hackenberg (2006) showed that the effects of tokens can vary depending on the context of both the token production and exchange schedules, and the same may also be true of the comparisons of the present research. Although examination of such a wide combination of component types across several token-production and exchange schedules was not practical for the present investigation, these manipulations would yield more detailed knowledge of stimulus function.

Third, in the present research for some subjects overall response rates tended to decrease across experiments. Because effects in the present experiment were assessed based on differences within a condition between the two different components this was not a major concern. However, an area for future research would be to investigate how performance varies as a function of amount of exposure to token-reinforcement
schedules. It may be that the determinants of behavior vary as experience with token schedules increases.

Lastly, the present procedures involve a dependent arrangement of token production and exchange schedules, with token production contributing to satisfying the exchange-production schedule. This need not be the case, however; the procedure could be modified such that producing an exchange would be independent of token production, given that at least one token had been earned. Under such an arrangement subjects could accumulate a number of tokens before completing a separate exchange ratio. In this case no relationship between number of tokens and proximity to exchange would exist; thus determinants of responding in an accumulation procedure might vary considerably from the token-reinforcement schedules presented presently.

Turning to broader issues, token-reinforcement procedures have been used extensively in applied settings with a wide variety of treatment populations (Kazdin & Bootzin, 1972; Kazdin, 1982). That token reinforcement schedules have been so widely used speaks to the importance of understanding of their controlling variables. By using nonhuman subjects in a precisely controlled environment the present research was able to contribute to the literature by showing that tokens have multiple functions depending on the contingencies. Data reported by Field, Nash, Handwerk, and Friman (2004) replicates the effects of exchange-schedule manipulations in a token reinforcement procedure in an applied setting. They found that decreasing the time between opportunities to exchange tokens for primary reinforcers, and thus increasing reinforcement rate, increased the effectiveness of a token economy in managing problem behavior.
The present data and prior token-reinforcement schedule research suggest several potentially fruitful extensions into applied settings. As mentioned earlier, token economies often are utilized as a means of reinforcing pro-social behavior. The present data suggest some of the circumstances that promote a discriminative rather than conditioned reinforcing function. For example, Experiment 3 showed that a correlation with number of tokens and temporal distance to exchange resulted in lower response rates than when this contingency was disrupted. Experiment 2 suggested that the duration of presentation may also determine the discriminative properties of tokens. One extension of these findings to applied research would entail comparing performance under briefly-presented token schedule, a token-schedule with an FR exchange, and a token-schedule with a VR exchange. Comparisons between these three arrangements would allow an assessment of how potential discriminative functions might disrupt responding maintained by tokens and methods of reducing any discriminative functions. Further research along these lines will add to the precision with which token reinforcement systems are implemented, and aid in managing behavior in multiple settings.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

I grew up in Oxford, North Carolina, attending public schools. After graduating from J. F. Webb High School in 1994, I enrolled as an undergraduate at the University of North Carolina at Wilmington (UNCW). I graduated from UNCW with a Bachelor of Arts in psychology with honors in the spring of 1999. The following fall I enrolled at the University of Florida in the graduate program in psychology in the behavior analysis area and began working in Dr. Timothy Hackenberg’s lab. My research at Florida has focused on choice, self-control, and schedules of token reinforcement.