

UNIVERSITY OF MANITOBA

THE STRUCTURE OF BEHAVIOR DURING FIXED-INTERVAL
SCHEDULES OF REINFORCEMENT

by

Brian L. Rector

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A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
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TO MY FATHER

who did not see me graduate,
but always knew I would.

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The structure of behavior during fixed-interval
schedules of reinforcement

by

Brian L. Rector

ABSTRACT

The key pecking of White Carneaux pigeons was maintained on one of four fixed-interval schedules of food reinforcement: FI 2, FI 4, FI 8 and FI 16 minutes. With the aid of two video cameras, a computer continuously tracked in three dimensions the position of the pigeon's head and/or neck region. Behavior waves were generated by examining distance from the head and neck region to the response key over time. Systematic changes in the behavior waves occurred within interreinforcement intervals, and across sessions. Five wave patterns were classified to describe the development of fixed-interval behavior. The predominant wave form associated with key pecks remained fairly constant for FI 2 and FI 4, showed some unsystematic changes for FI 8, and changed systematically for FI 16 when comparing early performance with steady-state performance. Certain high amplitude low frequency wave forms may have reflected the occurrence of interim activities. The results are discussed in relation to a variety of related theoretical issues: the definition of the operant, constituents of response rate, stimulus control, and interim activities.

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The structure of behavior during fixed-interval schedules of reinforcement

In attempting to accomplish the goal of predicting and controlling behavior, psychologists have distinguished two approaches to the analysis of behavior—functionalism and structuralism. The functional approach seeks to quantify relationships between behavior and environmental variables. The structural approach examines phenomena by identifying their basic elements and by describing how these basic elements form the phenomena of interest. Although functionalism and structuralism are viewed at times as opposing approaches, neither excludes the other (Catania, 1973b). It is the position of this author that a science of behavior, seeking to develop a high degree of prediction and control, must incorporate both the functional and complex structural aspects of behavior.

What aspects of behavior we measure, and how we organize our observations within a theoretical framework, will determine how well we can predict and control behavior. Skinner (1935, 1938) rightly argued that a science of behavior necessarily involves reproducible units; i.e., units that retain their identity across experiments. Otherwise, all occurrences of behavior would represent isolated phenomena from which general laws would be difficult, if not impossible, to derive. The unit advanced by Skinner to be reproducible was termed the operant (Skinner, 1969, p. 131). This unit is defined in terms of three factors: (1) a response class; (2) consequences which affect the probability of that response class; and (3) a stimulus class which precedes the response class, is correlated with the consequences of the response class, and thereby affects the probability of occurrence of the response class. The operant is therefore a functional unit of behavior.

Identification of an operant unit requires that the probability of a defined response class be affected by its consequences.

Skinner's concept of a reproducible unit also incorporated the assumption of a fairly constant structure; i.e., for the most part the movements that formed the members of the response class did not differ substantially from each other (Skinner, 1935, pp. 44-45). Skinner maintained that any estimate of the unit's strength could therefore be obtained by recording a portion or component of each response, since a change in the occurrence of the component would reflect a similar change in the occurrence of the entire unit. Typically, the one component recorded is that with which reinforcer presentation is contiguous (cf. Honig and Staddon, 1977).

Although the above method has led to the quantification of many functional relationships, it may not always provide an adequate view of some of the dynamic features of operant behavior. At least two variables may affect response rate as typically measured: (1) the amount of time allocated to the operant; and (2) the spatial character of the operant. The manner in which these variables change may affect the manner in which response rate changes. For example, an increase in the rate of key pecking may simply reflect an increase in the amount of time allocated to key pecking; or, contrary to the common view of the operant as a stereotyped unit, may reflect a decrease in the distance spanned by the pigeon's head while pecking (cf. Pear and Rector, 1979). Therefore, systematic changes in the occurrence of individual members of an operant's response class may affect response rate while the amount of time engaging in the operant remains unchanged. This possibility suggests that a further

understanding of the behavioral processes underlying variations in response rate might be obtained from a more complete functional-structural analysis of the operant unit.

The goal of the present experiment was to investigate systematically some of the structural components of behavior. To do so, however, required that we first specify for analysis some of the properties of a response that constitute its structure. In dealing with the structure of behavior, Skinner at one point (Skinner, 1953) discussed the concept of a behavioral element from which all behavior was composed. Although Skinner never defined a behavioral element, properties attributed to an element by Skinner may be derived from his analysis of response generalization:

What is the "transfer" which appears to strengthen behavior without reinforcing it directly? This is a good example of a pseudo problem. We divide behavior into hard and fast units and are then surprised to find that the organism disregards the boundaries we have set. It is difficult to conceive of two responses which do not have something in common. Sometimes the same muscular system is used. The effect of a reinforcement may reflect this fact rather than our arbitrary practice of calling the responses separate units.

...The traditional explanation of transfer asserts that the second response is strengthened only insofar as the responses "possess identical elements". This is an effort to maintain the notion of a unit of response. A more useful way of putting it is to say the elements are strengthened wherever they occur. This leads us to identify the element rather than the response as the unit of behavior. It is a sort of behavioral atom, which may never appear by itself upon any single occasion but is the essential ingredient or component of all observed instances. The reinforcement of a response increases the probability of all responses containing the same elements (Skinner, 1953, p. 94).

Schick (1971) points out Skinner's terminology here is confusing since it is not clear whether elements are operants or whether elements are properties of responses that define operants. This confusion may arise from

the fact that Skinner's behavioral element consists of two important properties: (1) a physical component of the organism; and (2) the component's spatial position. Considering these two properties together, the occurrence of a physical component at a particular spatial location may increase in frequency. For example, the rate of occurrence of a pigeon's beak touching a response key may increase. Considering only the spatial property of Skinner's behavioral element, a spatial location may procedurally define a movement or response as a member of an operant unit. For example, a key peck response may be defined as any movement that results in contact with the key. Thus, while the two properties of Skinner's behavioral element can form members of an operant unit, the spatial property of an element alone may specify that property of a response upon which reinforcers are contingent. Given this viewpoint of a behavioral element, a structural analysis of operant behavior will be outlined further.

In a typical operant experiment with rats, food presentation is made contingent upon a bar press defined by the closure of a switch. The response class, bar pressing, may involve a number of different physical components of the rat (eg., the right paw, the left paw, nose, tail, etc.) and no two movements or members of the response class need be identical in all respects. All the movements of the response class are similar, however, in that at one point the physical components involved occupy the spatial position specified by the shape and operating characteristics of the response bar. The defining property of this response class is therefore specified as a spatial position since it is this common property of the response upon which food is contingent. In addition, if the contingency between bar pressing and food

results in the response class increasing in frequency, the response class will have been functionally identified as an operant response class.

To summarize, for the purpose of the present discussion a defining property of a response class is that property upon which consequences are contingent. If, as a result of the contingency, members of the response class increase in frequency, the consequences will have been identified as reinforcers and the response class identified as an operant response class.

It has been argued that members of an operant, such as bar pressing, need only be defined as those instantaneous points in behavior associated with the closure of the switch, provided that these behavioral points function as an operant response class (Skinner, 1953, p. 95). The operant, however, has also been viewed as a broader functional unit of behavior (cf. Catania, 1973); i.e., all behavior that increases in frequency, as a function of the response-reinforcer contingency specified by the experimenter, forms the operant response class. According to the latter view of the operant, even though many of the behavioral elements comprising the movements to and from a response bar are never procedurally reinforced, they are also elements of the operant response class if their frequency increased as a function of procedurally reinforcing presses defined as switch closures. Members of an operant unit, thus defined, are movements comprised of behavioral elements.

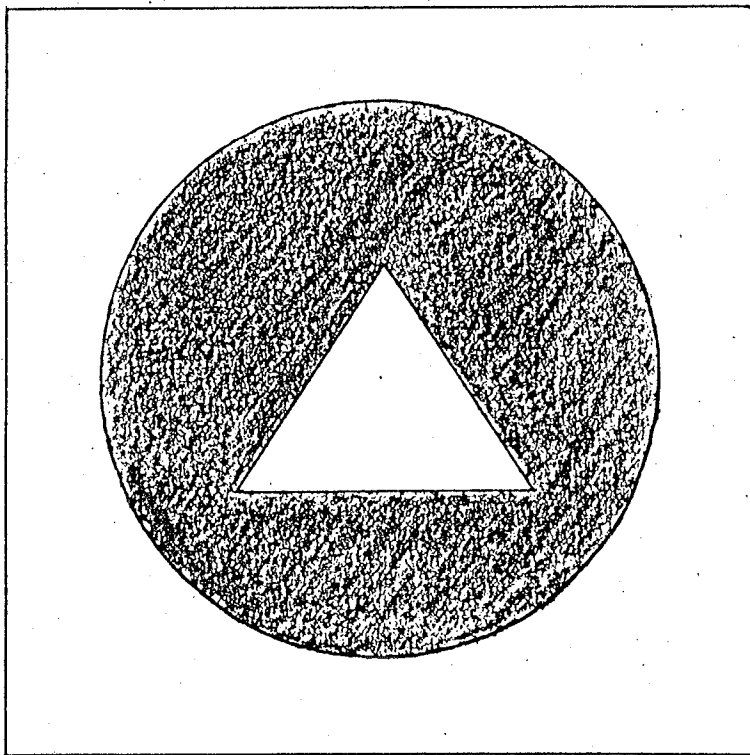
Members of an operant response class may therefore be defined as movements which are comprised of behavioral elements. Some of these elements may possess the defining property of the response class, while other elements may not. Thus, one may view the operant as a functional unit com-

prised of two sets of behavioral elements - a defining behavioral set, a set consisting of those elements that possess the property upon which reinforcers are contingent, and a nondefining behavioral set, a set consisting of those elements that do not possess the property upon which reinforcers are contingent. Figure 1 outlines in schematic form these categories of behavioral elements. The area of the square represents elements from a variety of activities that occur within a given period of time. The area of the circle represents only those elements that comprise the operant under consideration. Within the circle, the shaded area represents those elements that comprise the unit's nondefining set while the nonshaded area represents those elements that comprise the unit's defining set.

In summary, when one views the members of an operant as a movement, a structural analysis of an operant unit may involve at least two general components. First, the analysis identifies, operationally or functionally, those movements that constitute the unit's response class. Second, the analysis may describe the movements in terms of their physical components and spatial locations; i.e., their behavioral elements. From the latter information, the defining and nondefining behavioral sets of the unit may be derived and, if required, analyzed separately.

A structural analysis of an operant as viewed above presents at least four methodological problems. First, what determines the boundaries of a physical component? Second, how many physical components should one examine? Third, how does one differentiate between those movements that do and do not constitute members of a specific response class? Fourth, how does one examine the movement of a physical component? Before addressing these four issues it should be noted that they are not unique to a structural analysis

Figure 1. A schematic of behavioral sets. The area of the square represents the universal set of behavioral elements. The area of the circle represents all the behavioral elements that comprise a particular operant. The area of the triangle represents only those elements that possess the defining property of the operant.



of behavior. Similar problems were addressed by Skinner (eg., 1935, p. 40; 1938, p. 37) when he presented his functional analysis of behavior.

Concerning the first problem, defining the boundaries of a physical component, a structural analysis of a bar-pressing operant could observe the movements of the right paw or of each toe of the paw. Apart from technological problems, which approach is more appropriate will depend upon what questions the experimenter is addressing and the results obtained. If the former approach is adequate it would be preferred because of its relative simplicity. Therefore, the type of data derived from observing an experimenter-defined physical component determines whether or not the boundaries of the component were adequately specified.

Concerning the second problem, the number of physical components one should examine, members of a bar-pressing operant could involve the movements of both the right and left paws. It may not be necessary, however, to monitor the motions of both paws. If movements of the right paw were the most frequent members of the response class, or if the two types of movements occurred with the same relative frequency over time, monitoring only the right paw would be sufficient in most cases. If, however, one wished to investigate infrequent members of a response class, or if the frequency of the two types of movements demonstrated different functional relationships, monitoring the motion of the left paw or of both paws might be necessary. How many physical components one should examine is therefore determined by the nature of the phenomena one is investigating.

Concerning the third problem, differentiating on a moment-to-moment basis those movements that do and do not constitute members of a particular

operant response class, a number of definitions and procedures have been developed with varying degrees of success. One approach has been to define the members of an operant response class as those movements that result in interresponse times (IRTs) less than a specified duration (eg., Gilbert, 1958; Catania, 1961). Other procedures have relied on observers to judge whether or not a specific activity is occurring (eg., Rand, 1977; Shettleworth, 1975; Staddon and Simmelhag, 1971), or on behavioral control techniques that restrict a response class to a specific area defined by a platform which is then monitored (eg., Baum and Rachlin, 1969; Bouzas and Baum, 1976; Pear and Rector, 1979).

Concerning the fourth problem, examining the movement of a physical component, all investigations of behavior examine the movement of a physical component to one degree or another. For example, the methodology employed by Ferster and Skinner (1957) recorded when in time a physical component, a bird's beak, moved into the spatial location defined by a response key. As a structural analysis, however, the methodology is limited since a description of the beak's position at any given time is limited.

More complete structural analyses of behavior have been developed. One such development is the examination of IRTs (eg., Shimp, 1969). A systematic change in the movement of the physical component of interest is reflected by a systematic change in the time between occurrences of the defining behavioral set of the operant. Although demonstrated to be useful, an IRT analysis has some shortcomings. For example, movements may have very different forms but similar or equal IRT measures (Pear, Rector, and Legris, in press). It is therefore possible for an experimental manipulation, such

as the injection of a drug, to affect the behavior of an organism in a systematic manner without being reflected by a change in an IRT duration. Thus, depending upon the questions addressed by the experimenter concerning a given manipulation, an IRT analysis can have some shortcomings in comparison to a more detailed analysis of behavioral movements.

More complete spatial descriptions of operant behavior have resulted from dividing the defining behavioral set of an operant into a number of mutually exclusive subsets. For example, Antonitis (1951) defined the reinforced component of an operant as the placement of a rat's nose within a response slot. All placements of the nose within the slot constituted the operant's defining behavioral set. Antonitis divided the response slot into ten locations of equal length. Thus, the defining behavioral set of the operant was divided into ten possible subsets. By recording when a particular subset occurred, Antonitis was able to measure certain changes in the location of the rat's nose as a function of variables such as reinforcement frequency.

Dividing the defining behavioral set of an operant was also the strategy employed by Herrnstein (1961), Eckerman and Lanson (1969), and Boren, Moerschbaeche, and Whyte (1978). The first two studies used an elongated response key that was divided into ten possible behavioral subsets. By recording when each subset occurred, they were able to measure certain changes in the location of the bird's beak as a function of variables such as reinforcement frequency. The Boren et al. study was similar except that it divided the defining behavioral set of a bar-pressing operant by using a number of different manipulanda.

90 In addition to examining how the spatial location of a discrete response can vary, structural research has also examined how the force of movements may vary. Notterman and Mintz (1965), using rats, examined how bar pressing forces changed as a function of a variety of variables; eg., response-force requirements for reinforcer delivery, reinforcement frequency, and type of reinforcement schedule. With reinforcement contingent upon responses with forces within a specified range, the analysis allowed Notterman and Mintz to discriminate between two classes of bar presses - those bar presses that satisfied the reinforcement contingency and those that did not. The former responses comprise the traditional operant response class, while the latter responses comprise in part what is described in this paper as the non-defining behavioral set of the operant.

Other studies may be viewed as spatial analyses of the nondefining behavioral set of an operant, but these are few in number. Smith (1974), using pigeons and high speed photographic equipment, examined beak movements near a response key while key pecking was reinforced. In this experiment it was necessary to visually examine each picture to determine the movements of the beak. Rector (1977), using pigeons and a series of photocells that extended outward from a response key, examined seven spatial sets a pigeon's head could occupy while key pecking. Systematic changes in head movements were reflected by systematic changes in the proportion of time each spatial set was occupied.

Recent technological developments now make it possible to automatically and continuously monitor the movement of a pigeon's head throughout a chamber. Pear et al. (in press) used an apparatus consisting of two video

cameras providing perpendicular views of the experimental chamber. All objects in the viewing field of each camera were white except for the chamber's two clear glass walls through which the cameras viewed and a response key that was transilluminated red. The pigeon, a White Carneaux, was also white except for its head and neck region which was dyed black. Since the pigeon's head was the only dark area in the chamber, a computer that received the video signals from the cameras could track the movement of the head in three dimensions.

To summarize, no structural analysis can be said to be complete; however, some problems posed by a structural analysis of behavior appear to have been overcome or can be overcome with further empirical investigation. It is the opinion of this author that the comparatively small amount of research that has been done concerning the structure of behavior is attributable more to experimenter disinterest than to methodological difficulties. One can only speculate as to the reason or reasons for this disinterest. One reason may be the assumption that members of a response class are either similar in structure or do not change in a systematic manner with response rate (Skinner, 1938, p. 37; Nevin and Baum, 1980). This assumption has led to the position that a functional analysis of behavior can be adequately executed by examining those instantaneous components of behavior with which reinforcers are contiguous.

The latter position and procedure has been successful for many experimental purposes. As outlined earlier, however, a structural analysis of previously observed phenomena may provide additional relevant information.

To what extent new and relevant information can be derived from a structural analysis has yet to be fully assessed. Thus far, the research that has discriminated between several behavioral components has obtained new information relevant to the understanding of those behavioral processes reflected by changes in response rate. For example, it has been observed that along with changes in response rate the spatial location of the defining behavioral set of an operant changes systematically: (1) following a change in reinforcement frequency (Antonitis, 1951); (2) following a change in the type of reinforcement schedule (Boren et al., 1978); and (3) during the development of stable-state performance on a particular reinforcement schedule (Eckerman and Lanson, 1969). Similar findings have also been observed with response force (Notterman and Mintz, 1965); i.e., response force changes systematically: (1) following a change in reinforcement frequency and (2) following a change in the type of reinforcement schedule. In addition, it has also been observed that the frequency of certain members of a response class may in fact change systematically with response rate (Hearst, Koresko, and Poppen, 1964; Pear and Rector, 1979; Smith, 1974). The latter finding may have important implications for a quantitative analysis of behavior based solely on response rate (cf. Hearst et al., 1964; Blough and Blough, 1968; Pear and Rector, 1979).

To summarize, although certain developments have occurred in the structural analysis of behavior, to date little is actually known about the structure of behavior and if, when, and how variations in structure occur within such units of behavior as the operant. Presently a spatial description of those movements occurring during simple basic schedules of reinforcement is unknown.

The purpose of the present experiment was to extend our knowledge of the structure of behavior by collecting and analyzing data within the theoretical framework of operant behavior outlined earlier. In particular, using the previously described apparatus employed by Pear et al. (in press), the movement of a pigeon's head was continuously monitored while key pecking was reinforced on a fixed-interval (FI) schedule of food reinforcement; i.e., a schedule in which the first key peck after a specified period of time has elapsed is reinforced. The study examined response-rate patterns reflecting changes in the occurrence of actual key pecks (defining behavioral set) as correlated with structural patterns reflecting changes in the motion of the bird's head (nondefining behavioral set). This was done throughout the development of key-pecking behavior maintained on a variety of FI schedules.

Fixed-interval schedules were studied for a number of important reasons. First, previous research (Ferster and Skinner, 1957) has indicated the occurrence of a variety of response-rate patterns throughout the development of FI behavior. Examining the behavioral processes underlying a variety of response-rate patterns was therefore possible with FI schedules. Second, FI schedules have been valuable in examining a variety of related behavioral phenomena such as stimulus control (Wilkie, 1974), and adjunctive behaviors (Falk, 1961; 1971). A spatial analysis of FI behavior may therefore provide information concerning these phenomena. Finally, a spatial analysis of FI behavior may provide new information concerning a schedule that is often used, such as in the establishment of behavioral baselines in drug research, but not fully understood.

METHOD

Subjects

Eight experimentally naive male White Carneaux pigeons (P2A, P2B, P4A, P4B, P8A, P8B, P16A, P16B) served. All birds were maintained at 80% of their free-feeding weights throughout the experiment.

Apparatus

A three-key pigeon operant chamber with interior dimensions 57 x 57 x 37 cm was used. Only the left key of the response panel was operative. A key peck was recorded when a minimal force of 0.11N was applied to this key for a period of time equal to or greater than 18 ± 1 msec. The other two keys were covered with white cardboard. The operative key was 26 cm above the grid floor and was transilluminated with red light. An opening for presenting a food hopper was located 12 cm above the grid floor on the vertical midline of the response panel. Reinforcer presentations consisted of 3-sec access to the food tray which contained Purina Racing Pigeon Checkers.

The response panel, and one adjacent wall of the chamber, was white. All other walls and the ceiling were made of either clear glass or clear plexiglass. Two video cameras were placed within the experimental room approximately 1.10 m from the chamber. One camera was positioned for a near perpendicular view of the response panel, while the other camera was positioned for a near parallel view of the response panel. Both cameras viewed the entire chamber and were focused on the response key. The cameras photographed the chamber simultaneously every 1/30th of a second. Video

signals from each camera were transmitted to a micro-processor for analysis. The distance between the upper most visible point of that part of the pigeon dyed black (i.e., the head and neck) and the response key could be determined up to a maximum distance of 59 cm, a distance which spanned most of the chamber. When a bird occasionally moved beyond this distance, distance from head to key was recorded as 59 cm.

General illumination of the chamber was provided by fluorescent lamps attached to the ceiling of the experimental room. These lamps could be turned on or off by a relay. White noise was present in the experimental room at all times.

Procedure

Preliminary training. Prior to training, feathers on each bird's head and neck were dyed black. The birds were magazine trained by first continuously operating the food hopper until they approached and consumed grain from the hopper. The duration of each hopper operation was then gradually reduced until the birds approached and consumed grain from the hopper within 3 sec of its presentation. At all times the food aperture was illuminated by a hopper light. Upon operation of the food hopper, the intensity of the hopper light was increased.

After magazine training was completed, the response key was trans-illuminated red. For seven of the eight birds the response key was not illuminated during hopper operations. For the other bird (P16B), the key light always remained on and hopper operations resulted in the presentation of a buzzer and, as with the other birds, increased illumination of the

hopper. Key pecking was shaped and maintained for a minimum of five sessions on a continuous reinforcement schedule (CRF). Each of these sessions terminated after 60 feeder operations.

Fixed-interval schedules. After preliminary training each bird was introduced to an FI schedule of reinforcement employing a 4-min timeout (TO) procedure; i.e., immediately following each feeder operation all lights within the experimental room and chamber were turned off for a period of four minutes. After the TO had elapsed, all lights were turned on and timing of the FI schedule commenced. The first key peck after the scheduled interval had elapsed operated the food hopper. The FI schedule differed for each bird, but for pairs of birds the schedules were very similar. The schedule for each bird was: P2A - FI 2.01 min; P2B - FI 2.05 min; P4A - FI 4.06 min; P4B - FI 4.10 min; P8A - FI 8.02 min; P8B - FI 8.20 min; P16A - FI 16.06 min; P16B - FI 16.47 min. For convenience, this report will refer to the above pairs of schedules as FI 2, FI 4, FI 8, and FI 16 min, respectfully.

All sessions terminated after 20 feeder operations or three hours, whichever occurred first, for the FI 2 min and FI 4 min schedules. All sessions terminated after 12 and 6 feeder operations (or three hours) for the FI 8 min and FI 16 min schedules, respectively.

RESULTS

For all eight birds, the transition from early to late FI performance was characterized by the progressive development of five behavior-wave patterns; i.e., patterns that show how the distance between the region of the pigeon's head and the response key changes over time within an inter-reinforcement interval (IRI). These five wave patterns will be referred to as Stages 1 to 5, respectively, and are displayed in Figures 2 to 26. For the purpose of condensing the data for these figures, every eight consecutive data points (4/15 sec) were averaged.

Stage 1. Figures 2 to 6 show a behavior pattern typical of the first few intervals following CRF. For all schedules, the rate of key pecking diminished across the IRI and reinforcement typically occurred well after its scheduled availability. Near the start of each IRI, low amplitude high frequency waves were interspersed among high amplitude low frequency waves. As the interval progressed some approaches to the key did not result in key pecks. These latter approaches shall be referred to as nondefining approaches since they do not contain the defining property of the key-peck operant. The pattern of alternating between high and low amplitude waves, in the absence of key pecks, either persisted until a peck finally occurred to terminate the IRI (eg., see Figure 4, P8B), or the peaks of the high amplitude waves increased in duration until an eventual approach to the key and a key peck terminated the wave and the IRI, respectively (eg., see Figure 5).

Stage 2. Figures 7 to 11 show a behavior pattern that began approximately fifteen IRIs following CRF. There was a very short post-reinforcement pause (PRP - time from the start of the interval to the first key peck) followed by an irregular moment-to-moment rate of pecking for the remainder of the IRI. Across the IRI the wave pattern consisted of low amplitude high frequency waves interspersed among high amplitude low frequency waves. Non-defining approaches occurred throughout the IRI.

Stage 3. Figures 12 to 16 show a behavior pattern that began to occur between approximately twenty to thirty IRIs following CRF. The PRP was longer than that shown for Stage 2; consequently, most of the key pecks now occurred in the latter half of the IRI, but during this time moment-to-moment rate of pecking still varied in an irregular manner. During the PRP the birds were fairly still (eg., see Figure 12, P2B), although it was not uncommon for nondefining approaches to have occurred throughout the duration of a PRP (eg., see Figure 14, P8B). Following the PRP, high and low amplitude waves occurred for the remainder of the IRI.

Stage 4. Figures 17 to 21 show a behavior pattern that began to occur approximately fifty IRIs following CRF. Stage 4 never completely ceased to occur within a session even after the birds had received prolonged exposure to their FI schedule. This was especially the case with the higher FI schedules.

The figures for Stage 4 indicate that the PRP was now longer than that observed for Stage 3, and positive acceleration in rate of key pecking now occurred across the IRI. The wave pattern showed three phases: an initial phase at the start of the IRI during which time the bird was fairly still,

a transition phase where high amplitude waves were interspersed among low amplitude waves, and a terminal phase during which time the amplitude of the waves were generally lower than that observed during the transition phase. For the FI 2 and FI 4 schedules, the terminal phase consisted mainly of low amplitude high frequency waves (see Figures 17 and 18). Except for P8A, the terminal phase for the FI 8 and FI 16 schedules was characterized by low and moderately high amplitude waves (see Figures 19, P8B; 20, 21). The change from the transition to the terminal phase could either be quite abrupt (eg., see Figure 19; P8A) or quite gradual (eg., see Figure 19; P8B). Nondefining approaches occurred frequently during the transition phase and at times comprised much of a PRP (eg., see Figure 19; P8B).

Stage 5. Figures 22 to 26 show a behavior pattern that began to occur between approximately eighty to one hundred IRIs following CRF. The pattern consisted of a long PRP followed by a brief acceleration to a moderate or high pecking rate that then persisted for the remainder of the interval. The wave pattern was similar to that of Stage 4 except that the transition phase between the initial and terminal phase was now considerably shorter in duration. Nondefining approaches were now quite rare for those intervals that showed a short transition phase (eg., see Figures 22 and 23), but still occurred for those intervals where the transition phase, although diminished relative to Stage 4, was to some extent still present (eg., see Figure 24, P8B). Only the terminal phase for the FI 16 schedule was characterized by both moderately high and low amplitude waves. The terminal phase for the other schedules consisted mainly of low amplitude high frequency waves.

Key pecks and associated wave forms. Visual inspection of Figures 2 to 26 indicate that key pecks tended to be associated with low amplitude high frequency waves. An analysis was conducted to determine whether or not there was a predominant wave form associated with pecks, and whether this predominant wave form changed systematically over phases. The key pecks shown in Figures 2 to 26 (N = 3156) were categorized as to whether or not they had been immediately preceded by a low amplitude high frequency wave. A low amplitude high frequency wave was defined as a wave with an amplitude of 10 cm or less occurring within a period of 5 secs.

Table 1 shows the percentage of key pecks associated with low amplitude high frequency waves for each of the five stages for each bird. For the FI 2 and FI 4 birds, 18 of the 20 cells in the matrix show that key pecks were associated with low amplitude high frequency waves 75% of the time or greater, and that there was no systematic tendency for this distribution to change over stages. For the FI 8 birds, 7 of the 10 cells in the matrix show that key pecks were associated with low amplitude high frequency waves 75% of the time or greater. Again, there appears to have been no systematic change in the distribution of these waves. For the FI 16 birds, only 4 of the 10 cells in the matrix show that key pecks were associated with low amplitude high frequency waves 75% of the time or greater. In addition, for the FI 16 birds there was a tendency for key pecks to be less associated with low amplitude high frequency waves over time. By Stage 5 (steady-state) only 50% and 27% of the key pecks were associated with low amplitude high frequency waves for P16A and P16B, respectively.

Thus, the data indicate that key pecks were predominantly associated with low amplitude high frequency waves for the FI 2 and FI 4 schedules over all 5 stages. In comparison with this schedule, a greater proportion of the key pecks were associated with wave forms with either moderate or high amplitudes (>10 cm) for the FI 8 schedule, but no systematic changes occurred over the 5 stages. On the other hand, pecks associated with moderate or high amplitudes increased in proportion when comparing early FI 16 performance with steady-state FI 16 performance.

Interobserver reliability. An interobserver reliability check was conducted involving each developmental stage for each bird of the study. When possible, the experimenter selected 25 graphs for each bird, five graphs for each phase. These graphs were in addition to those graphs shown in Figures 2 to 26. For birds P2B, P4B, and P8B 24, 22, and 21 graphs were selected, respectively. The missing graphs for these birds were from either Stage 1 or Stage 2, where possibly the speed of development for these stages did not allow a full complement of five graphs per phase. In total, 192 graphs were selected for the interobserver reliability check.

The five graphs from Figures 2 to 26 representing each stage for a bird were presented and explained to an observer. The observer was then asked to examine the graphs selected by the experimenter for that bird and to determine what phase or wave pattern was represented by each graph. The observer was instructed to put a graph off to the side if he felt that a wave pattern was not represented by any one of the five stages. The above procedure was conducted for all eight birds. Interobserver reliability

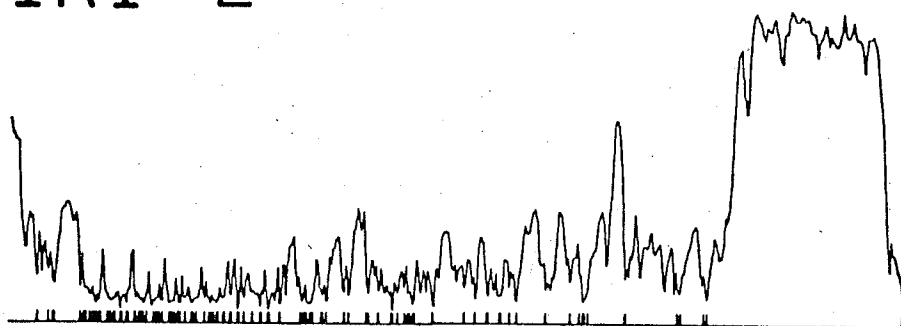
was calculated as the total number of agreements divided by total number of agreements plus disagreements. Reliability was established at 98.9%.

The high interobserver reliability measure indicates that each of the five wave patterns shown in Figures 2 to 26 are not anomalies since they are similar to other wave patterns collected for each bird.

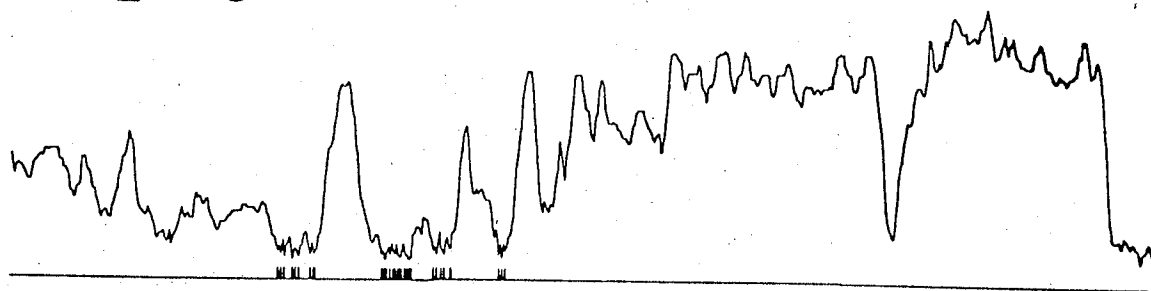
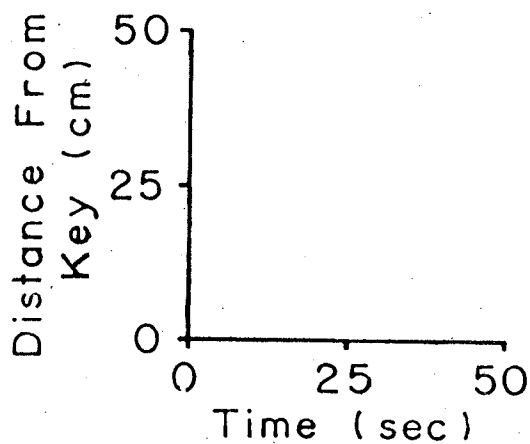
Figure 2. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 2-min Stage 1 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 2 Stage 1

P2A
IRI # 2



P2B
IRI # 6



10% to 2 in
FI

Figure 3. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 4-min Stage 1 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

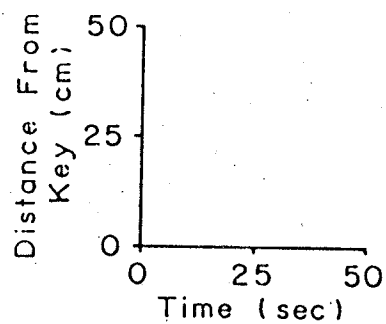
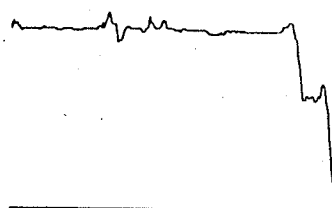
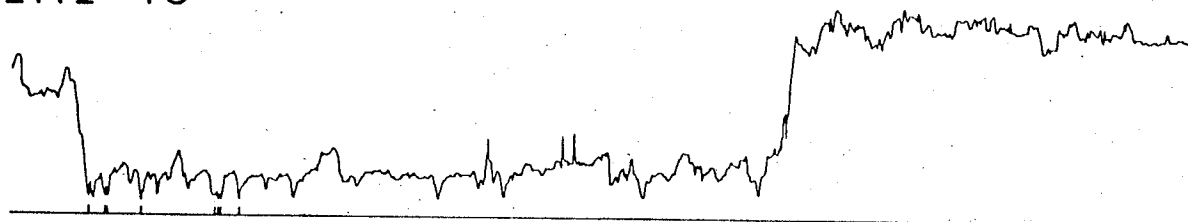
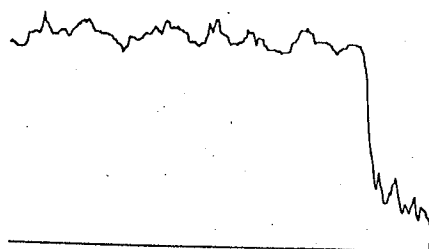
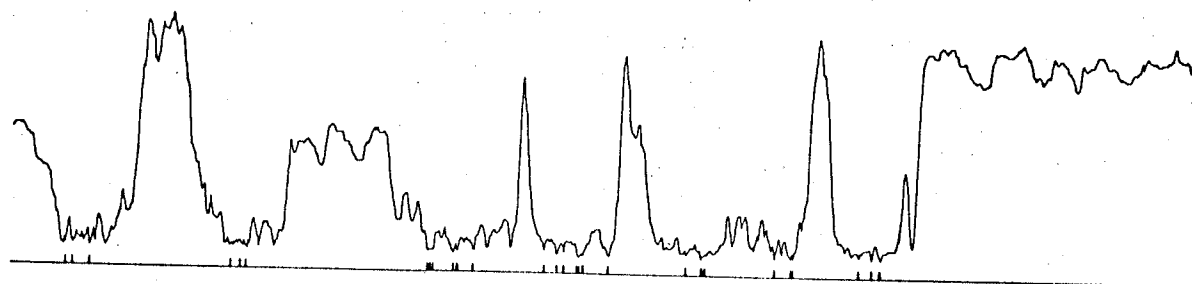
FI 4
Stage IP4A
IRI #10P4B
IRI #1

Figure 4. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 8-min Stage 1 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

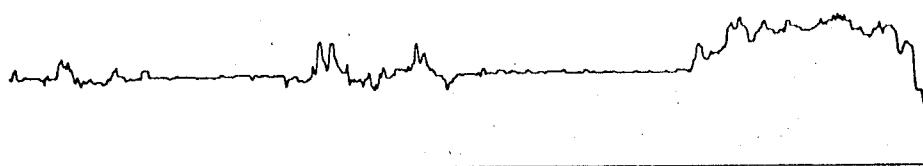
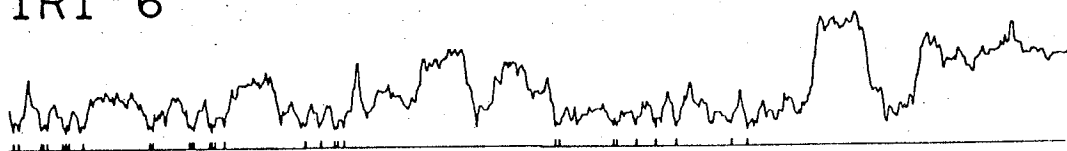
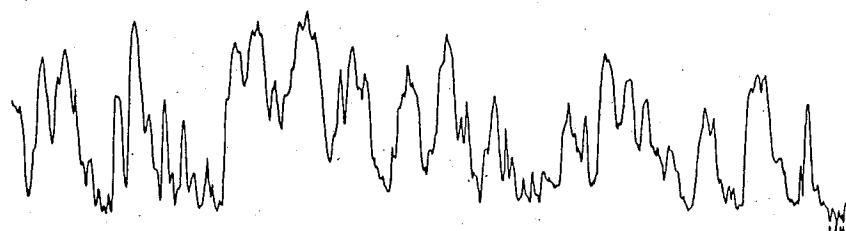
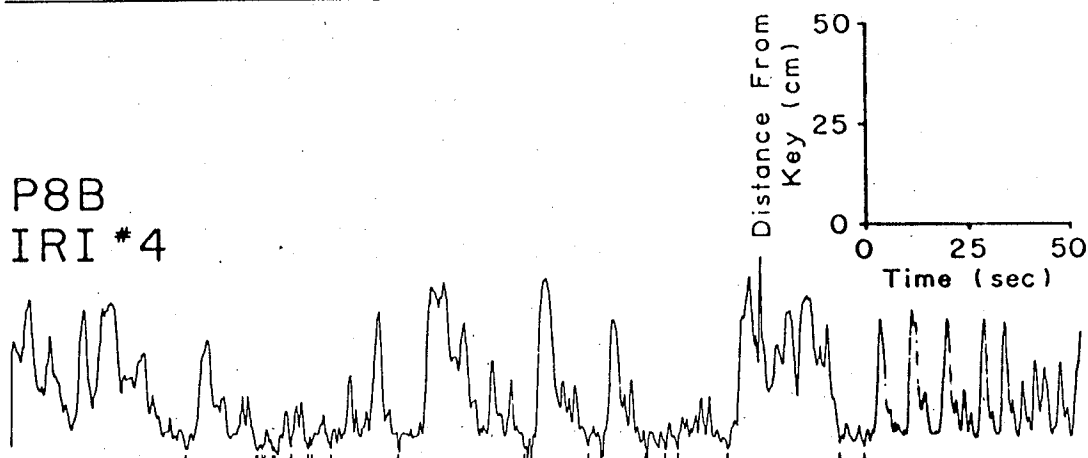
FI 8
Stage IP8A
IRI * 6P8B
IRI * 4

Figure 5. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 1 performance (P16A). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

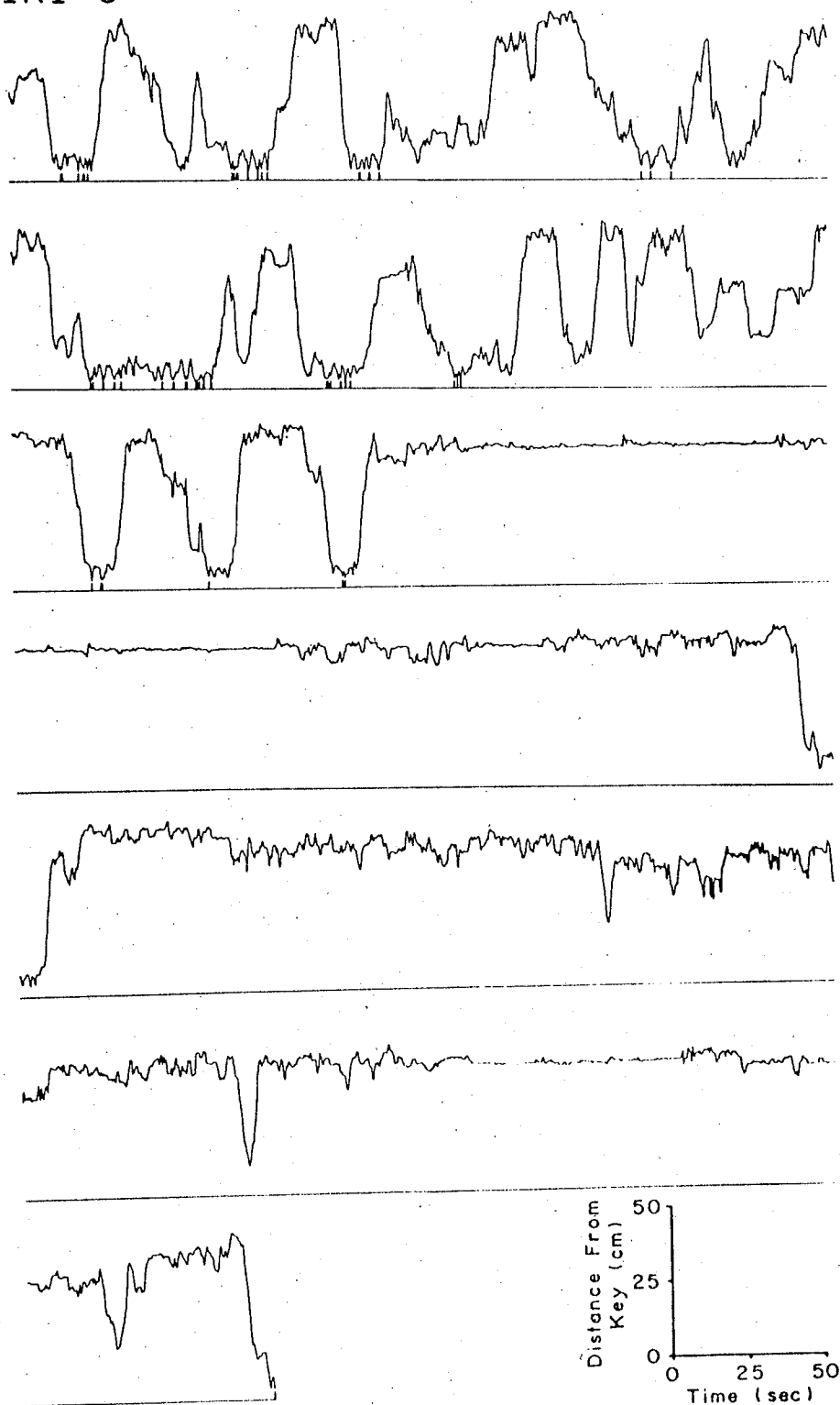
FI 16
Stage IPI6A
IRI *6

Figure 6. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 1 performance (P16B). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 16
Stage I

PI6B
IRI #3

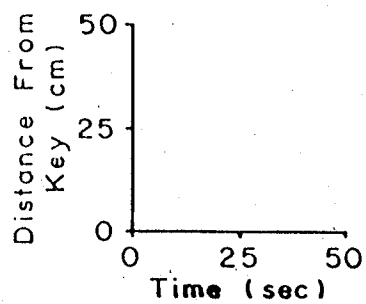
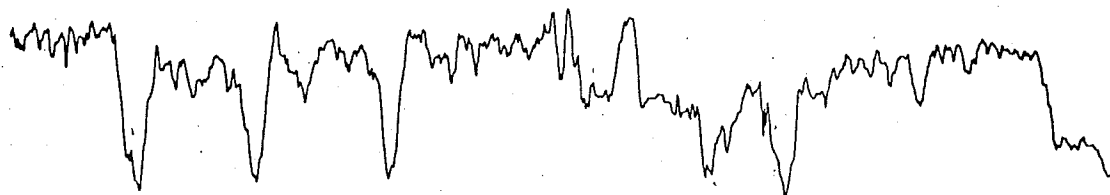
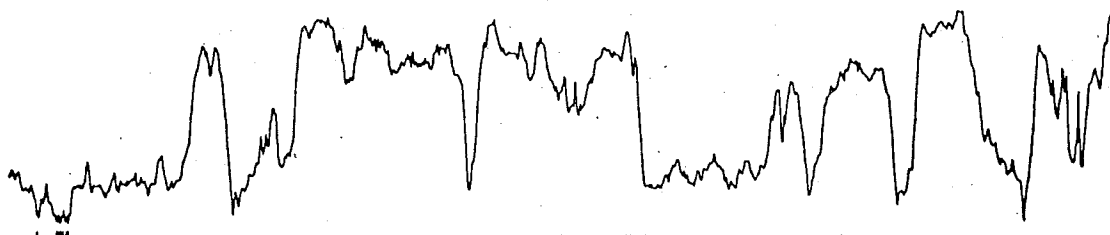
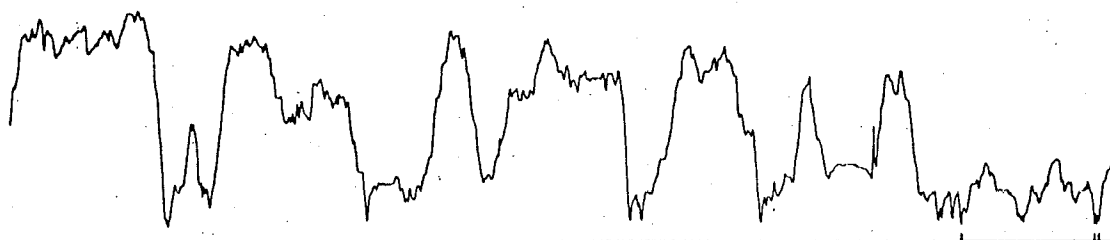
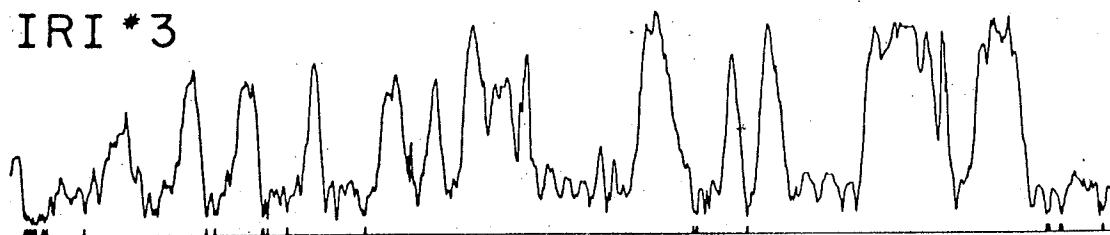
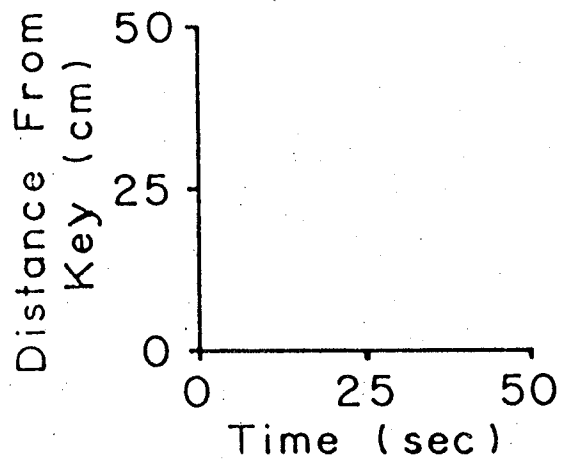
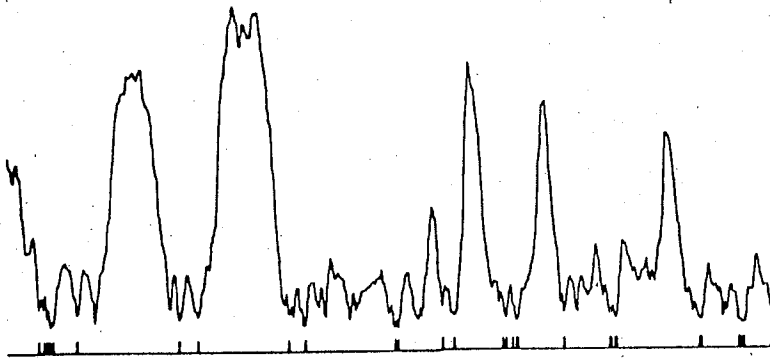


Figure 7. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 2-min Stage 2 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 2
Stage 2

P2A
IRI # 22



P2B
IRI # 17

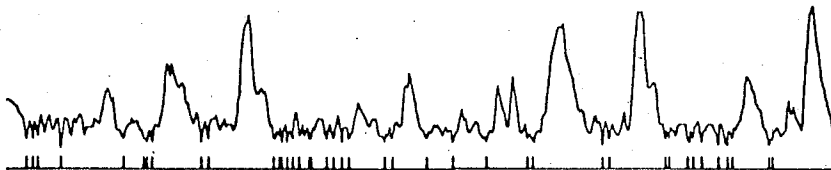
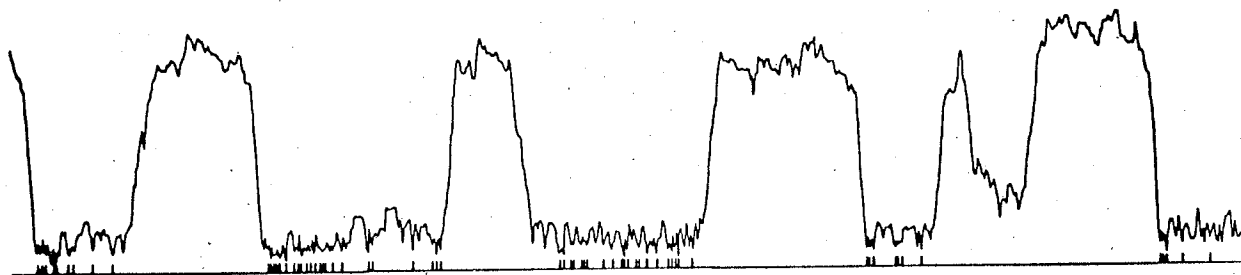


Figure 8. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 4-min Stage 2 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 4
Stage 2

P4A
IRI #40



P4B
IRI #22

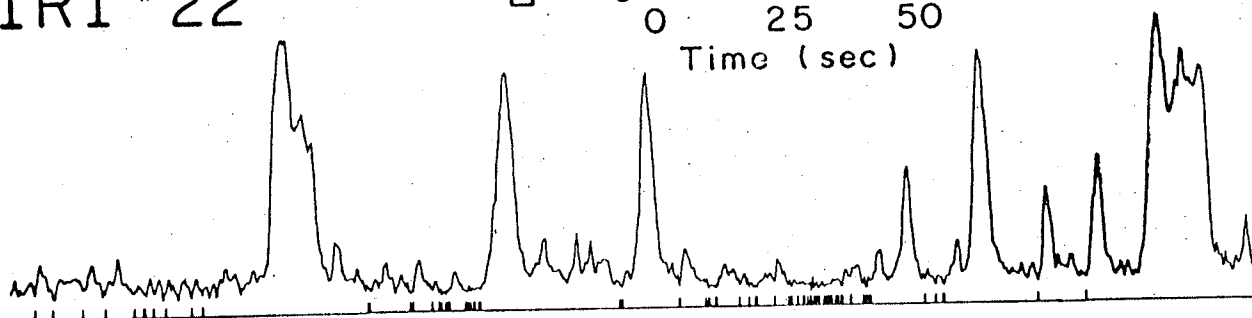
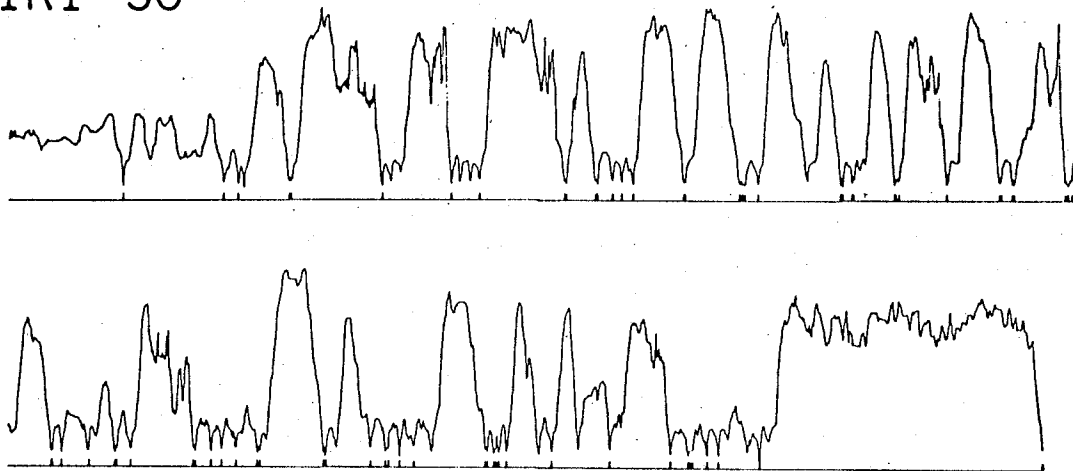


Figure 9. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 8-min Stage 2 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 8
Stage 2

P8A
IRI * 30



P8B
IRI * 14

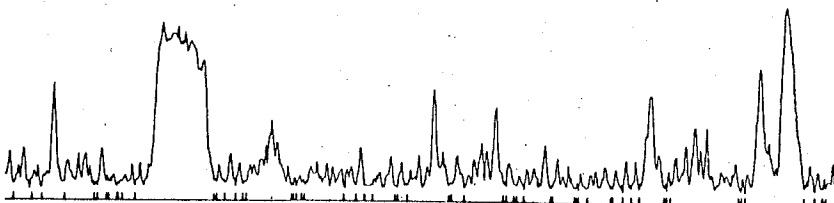
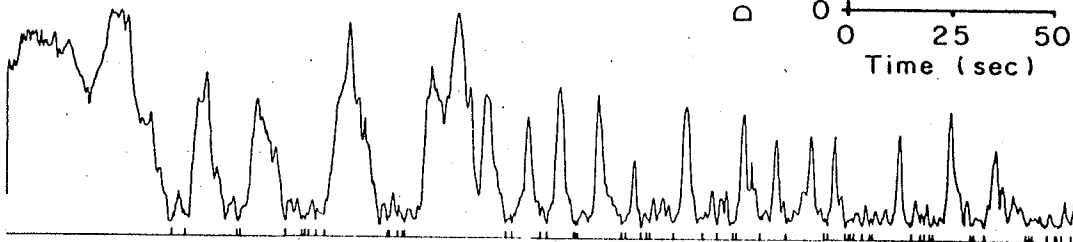
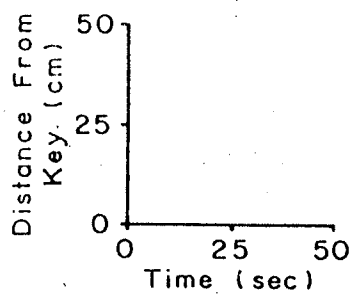
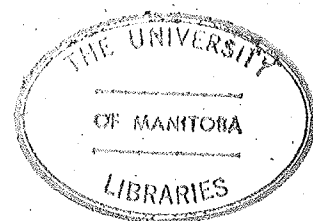


Figure 10. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 2 performance (P16A). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.



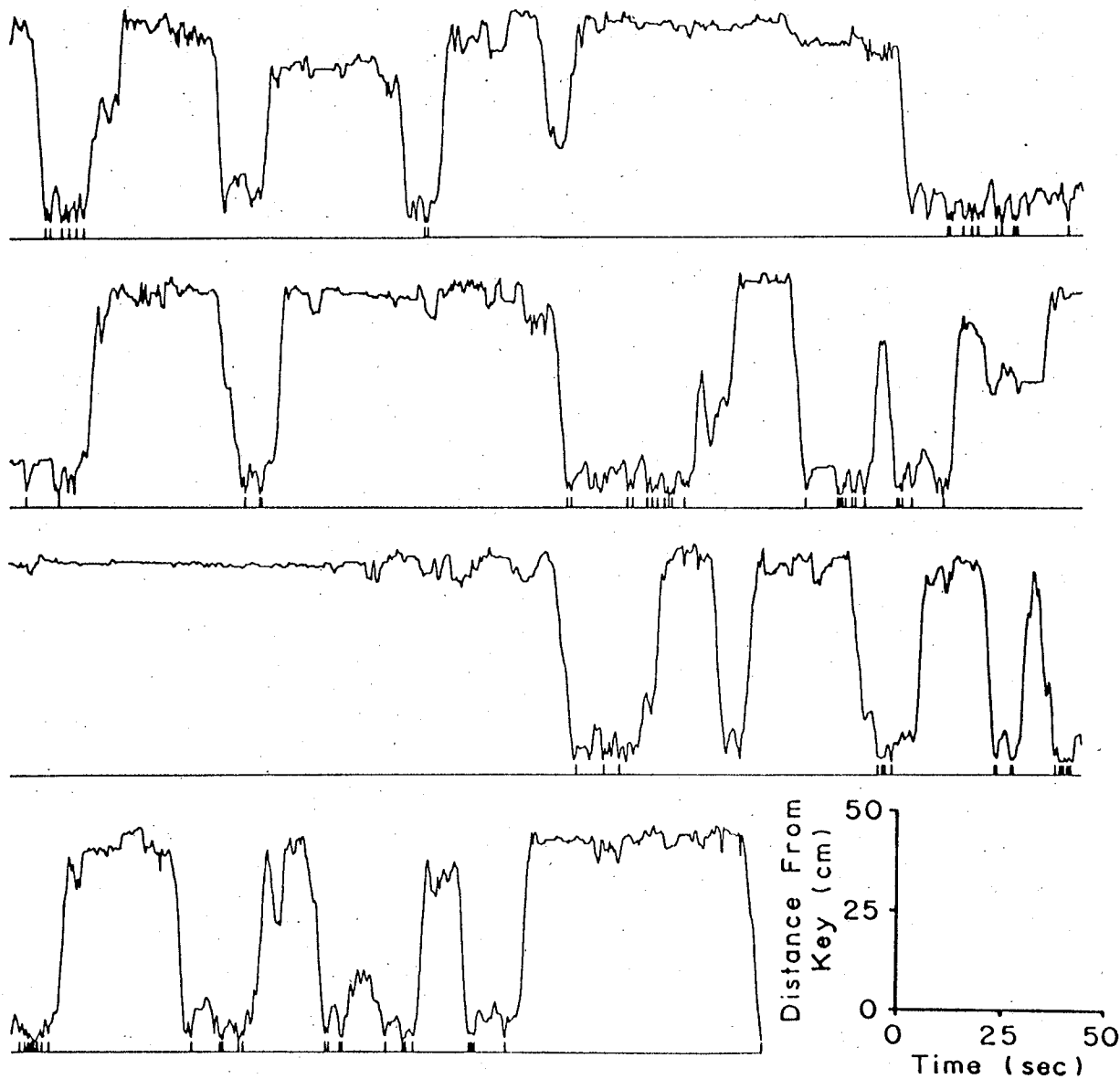
FI 16
Stage 2PI6A
IRI * II

Figure 11. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 2 performance (P16B). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

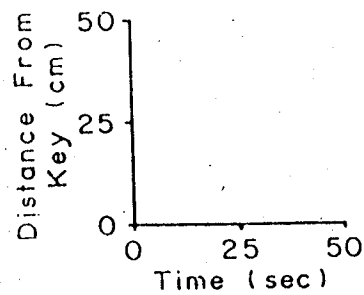
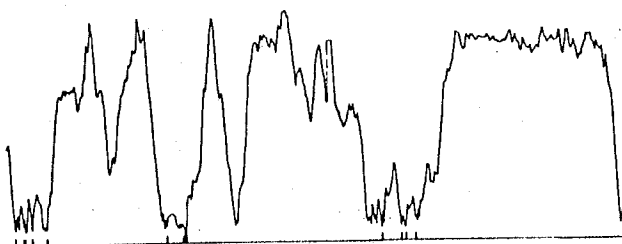
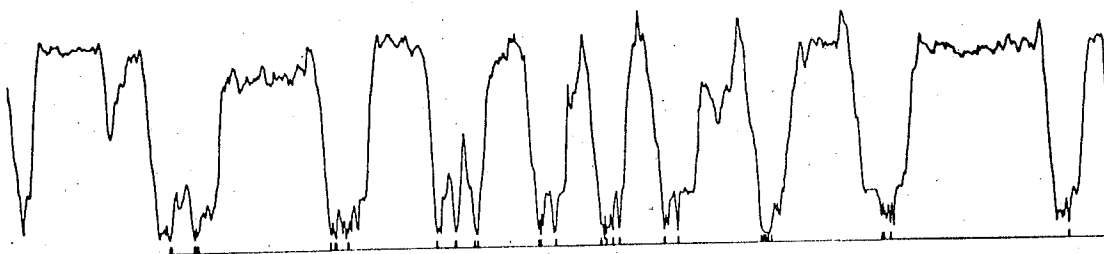
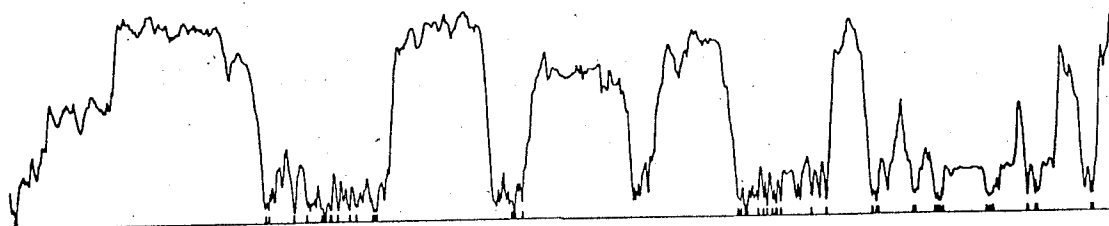
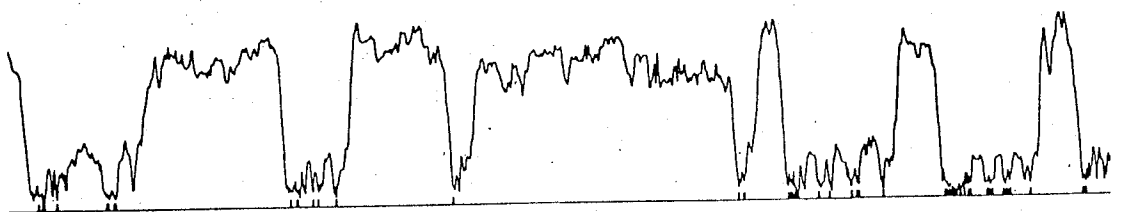
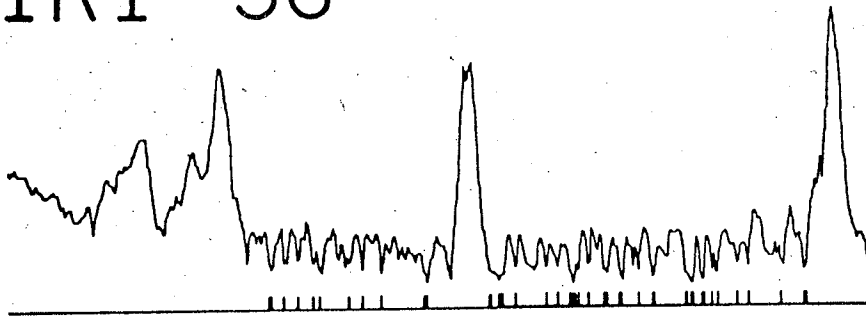
FI 16
Stage 2PI6B
IRI #13

Figure 12. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 2-min Stage 3 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 2 Stage 3

P2A
IRI # 36



P2B
IRI # 24

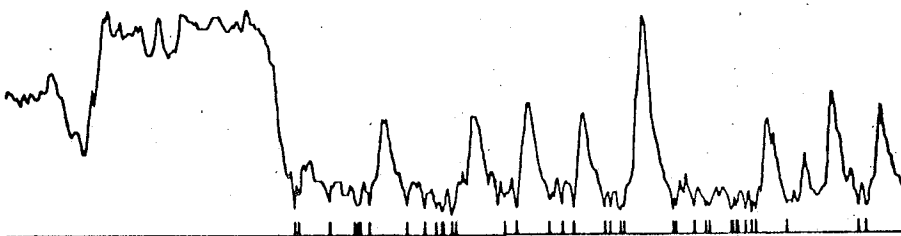
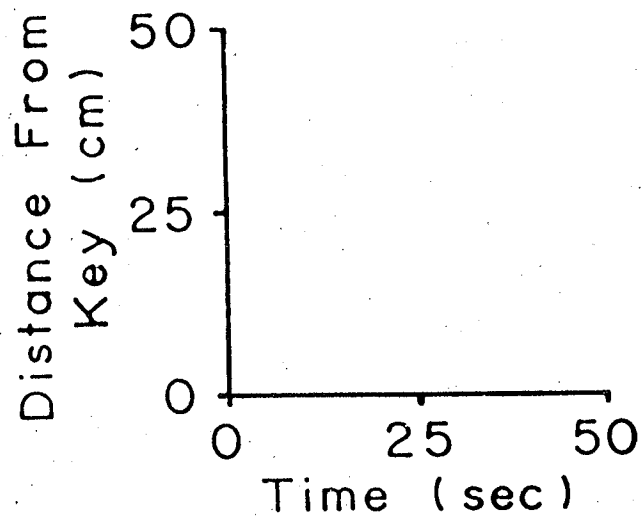
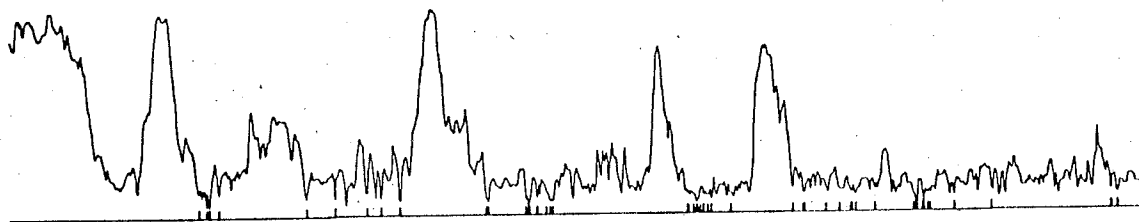


Figure 13. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 4-min Stage 3 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 4
Stage 3

P4A
IRI # 23



P4B
IRI # 21

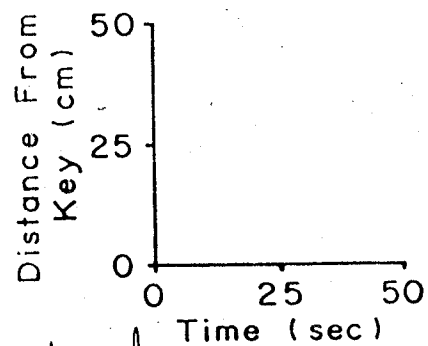
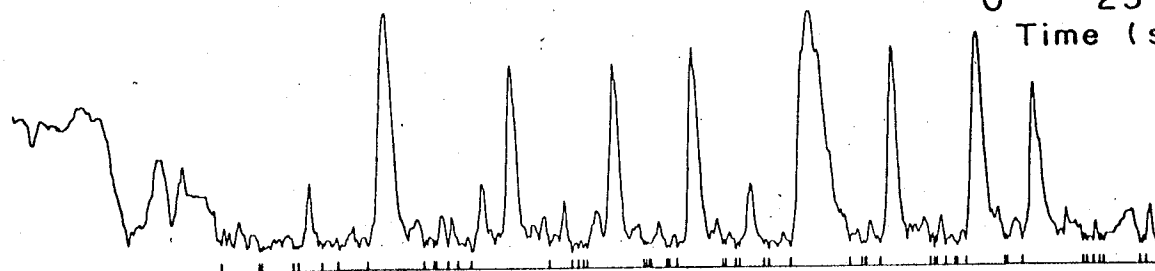
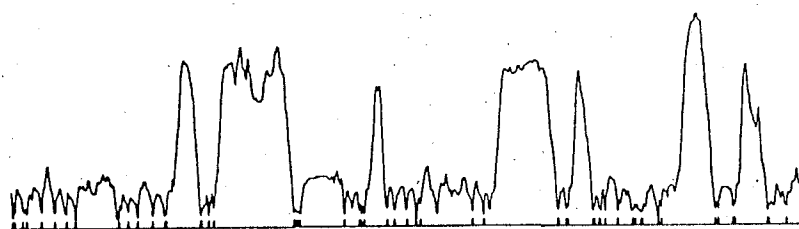
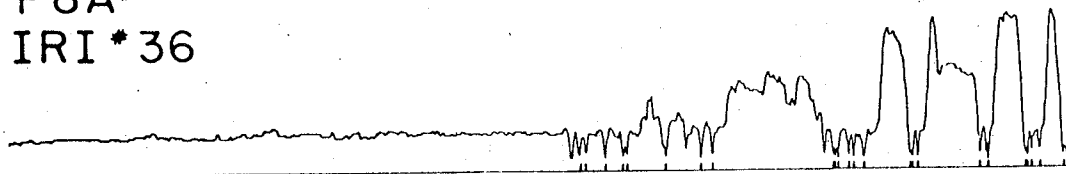


Figure 14. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 8-min Stage 3 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 8
Stage 3

P8A
IRI * 36



P8B
IRI * 17

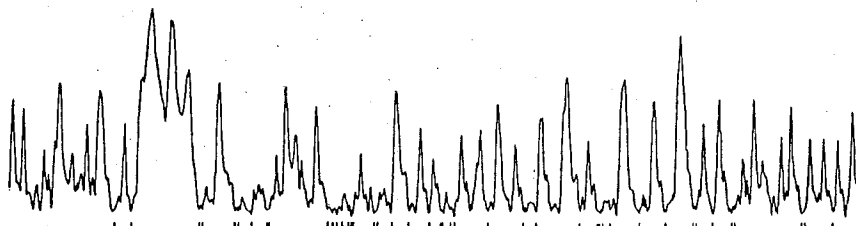
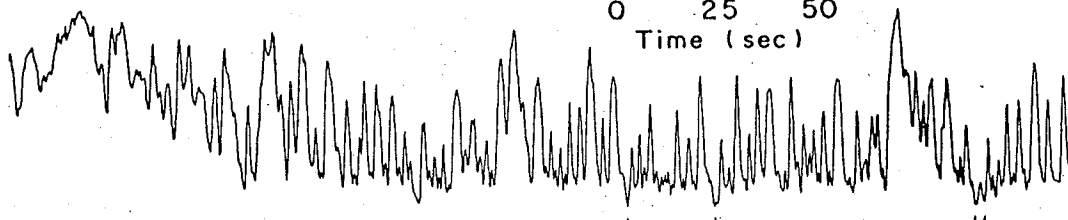
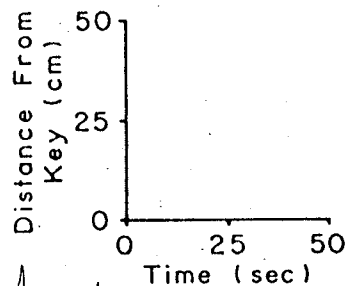


Figure 15. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 3 performance (P16A). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

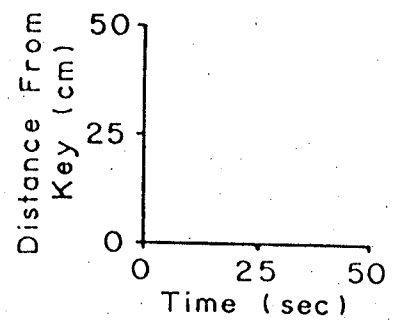
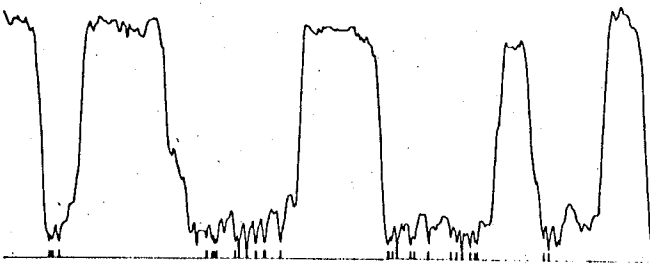
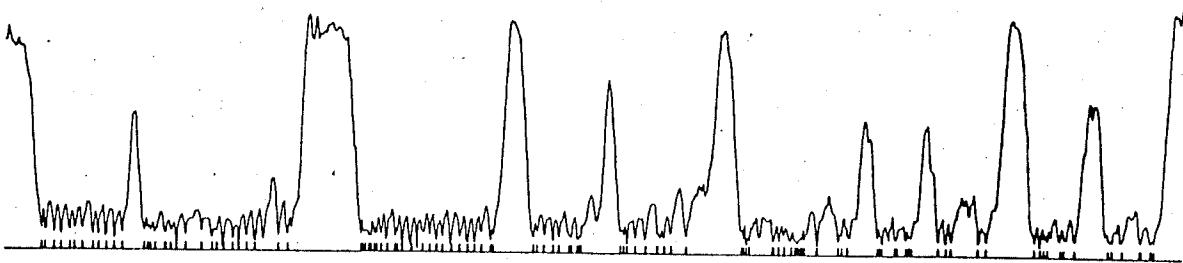
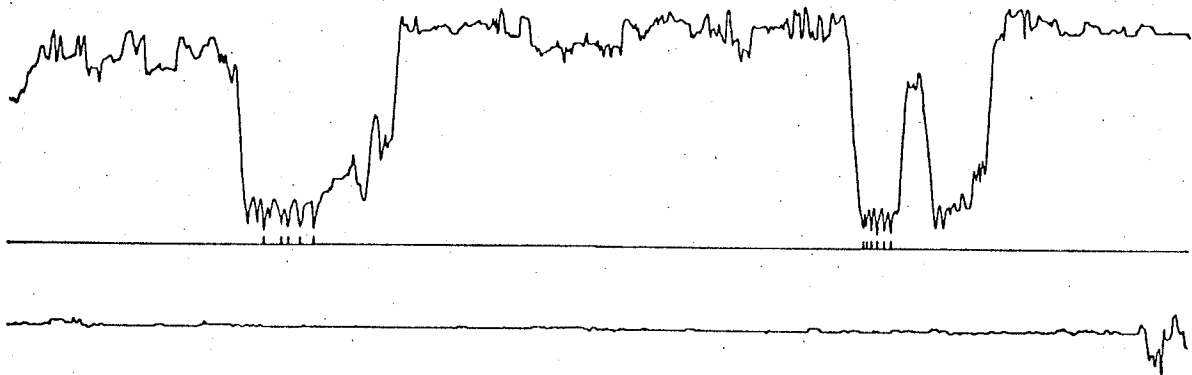
FI 16
Stage 3PI6A
IRI # 24

Figure 16. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 3 performance (P16B). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 16
Stage 3

PI6B
IRI #22

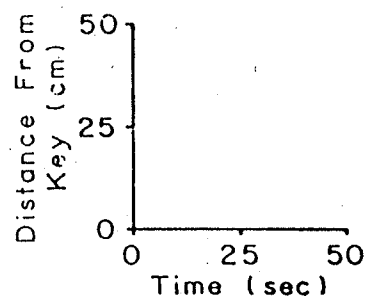
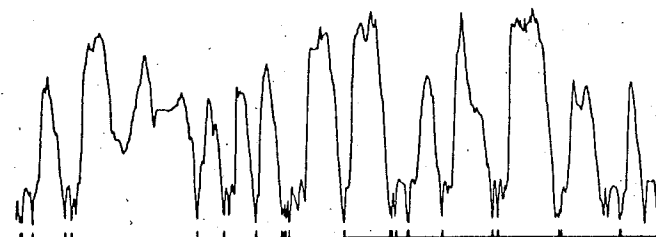
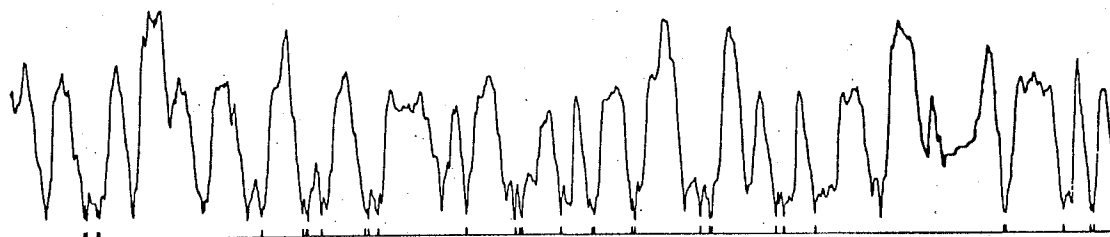
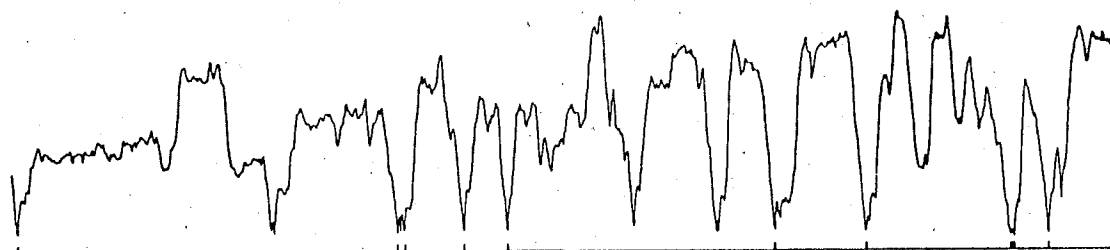
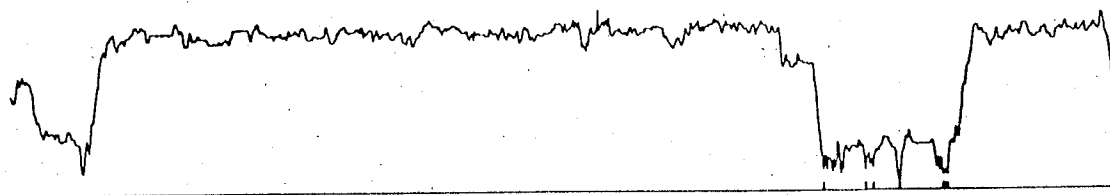
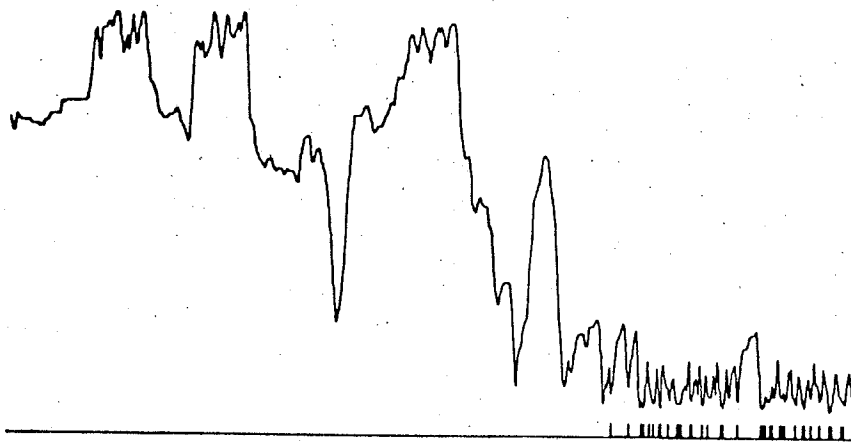


Figure 17. Selected IRLs showing distance from the region of the pigeon's head to the response key for FI 2-min Stage 4 performance.

The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 2
Stage 4

P2A
IRI # 217



P2B
IRI # 71

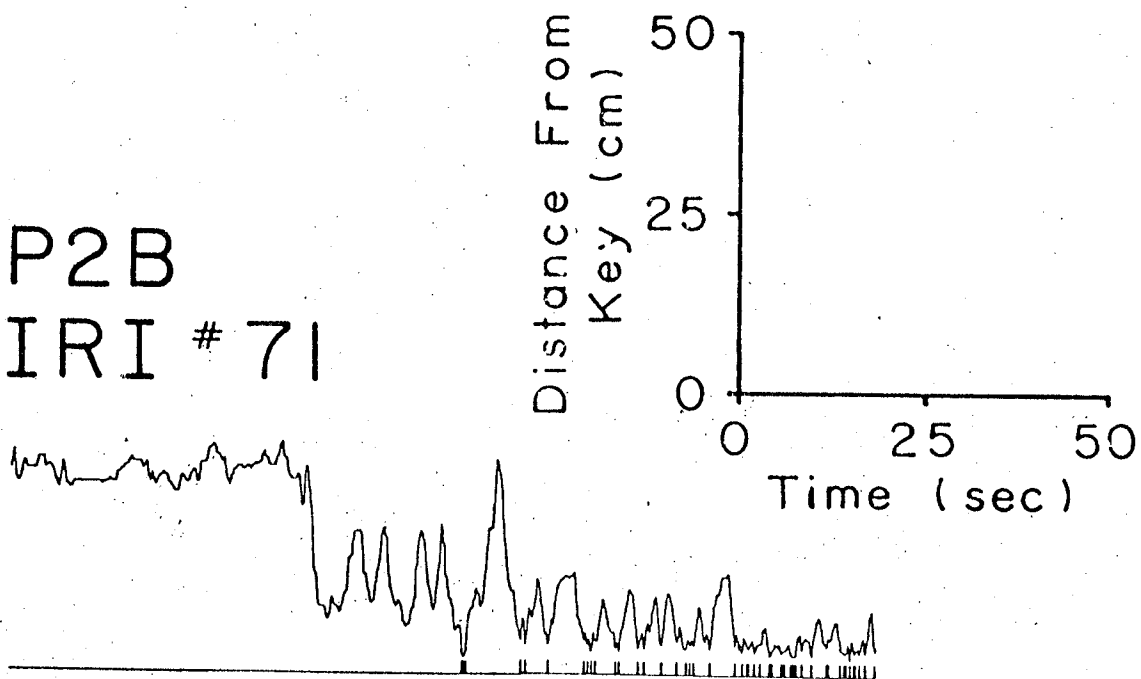
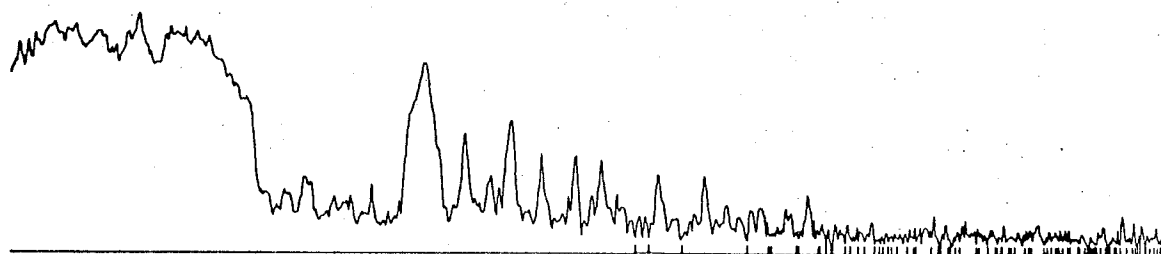


Figure 18. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 4-min Stage 4 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 4
Stage 4

P4A
IRI #88



P4B
IRI #45

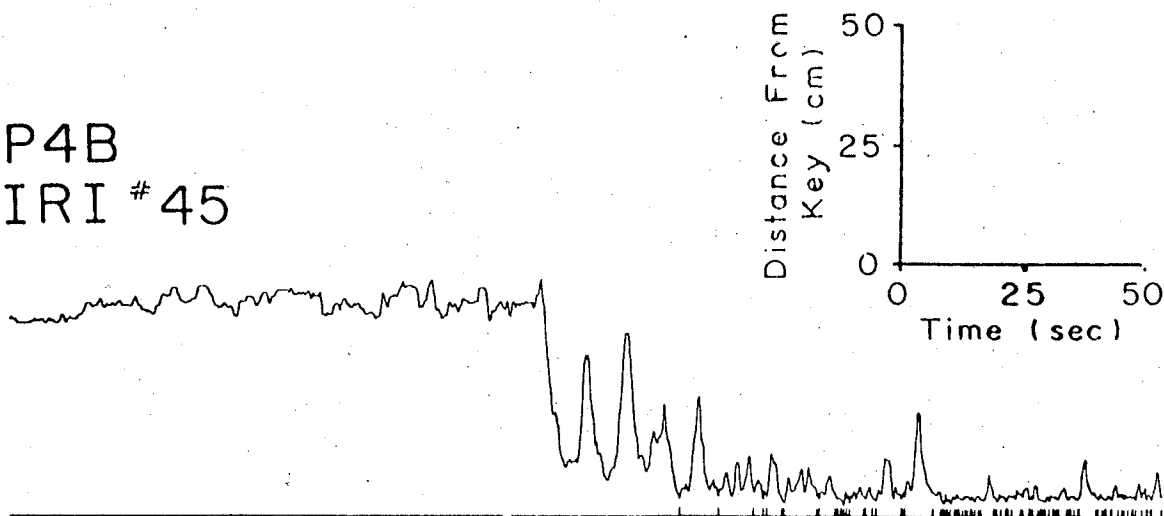


Figure 19. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 8-min Stage 4 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

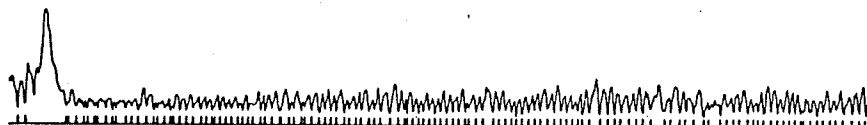
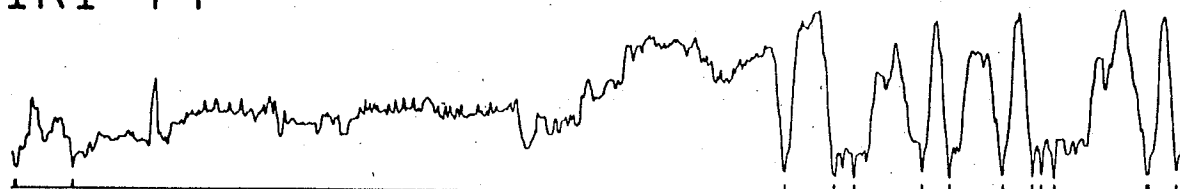
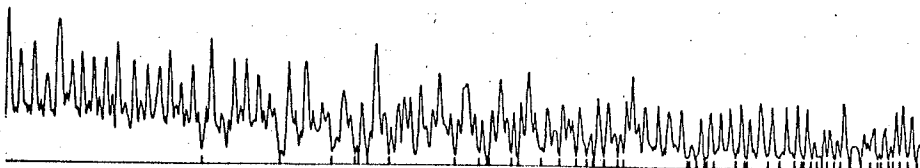
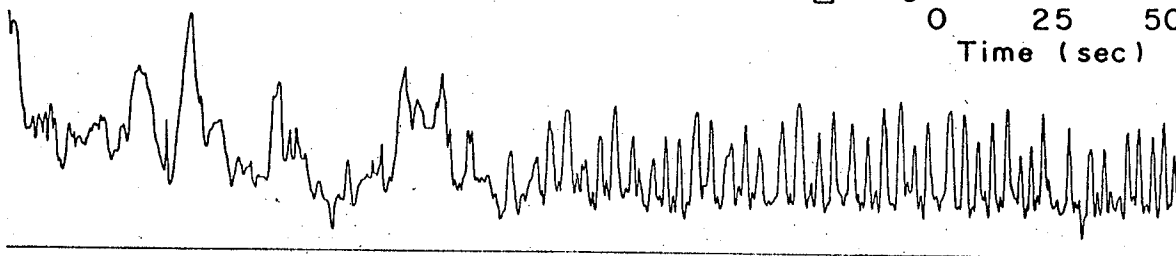
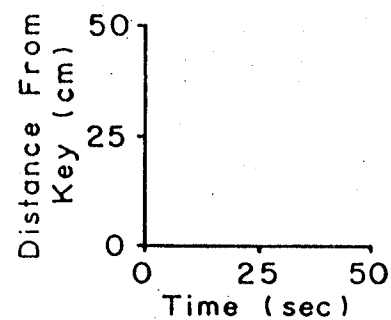
FI 8
Stage 4P8A
IRI #74P8B
IRI #88

Figure 20. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 4 performance (P16A). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 16
Stage 4

PI6A
IRI #70

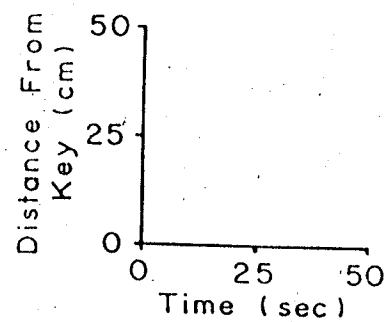
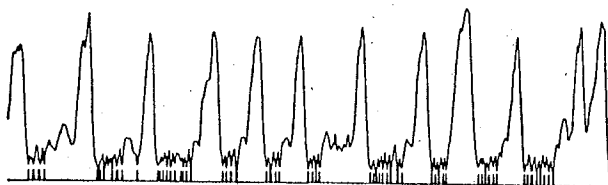
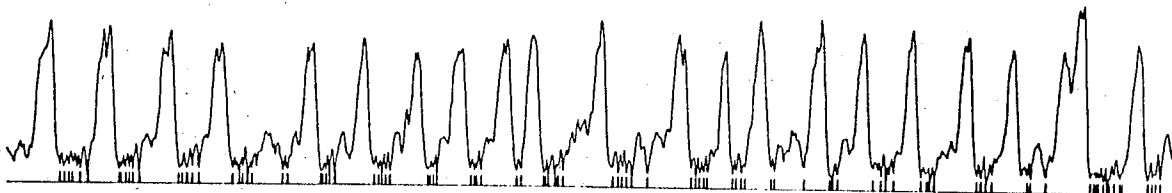
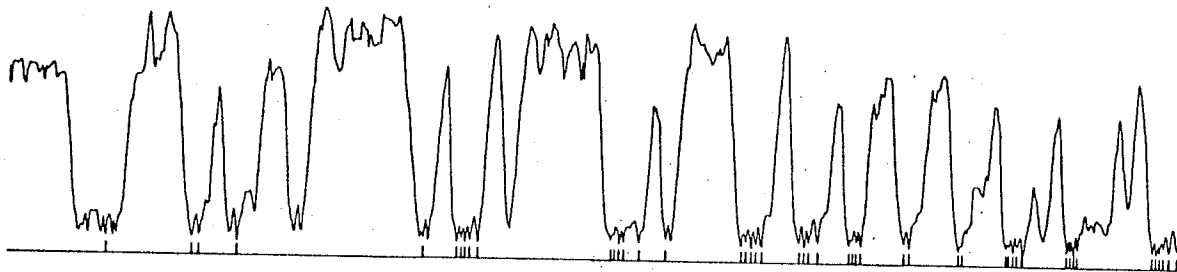
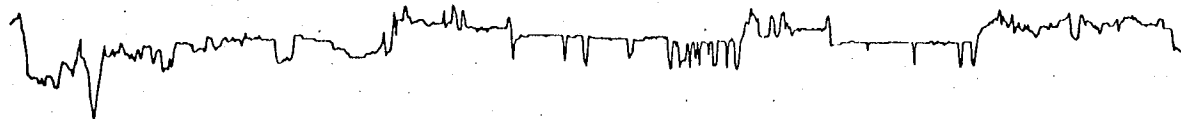


Figure 21. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 4 performance (P16B). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 16
Stage 4

PI6B
IRI # 42

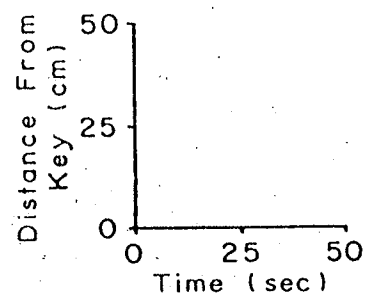
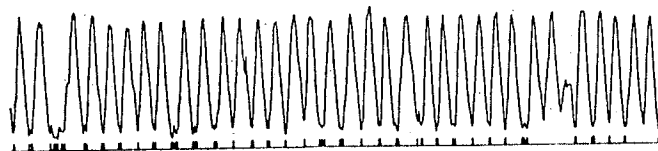
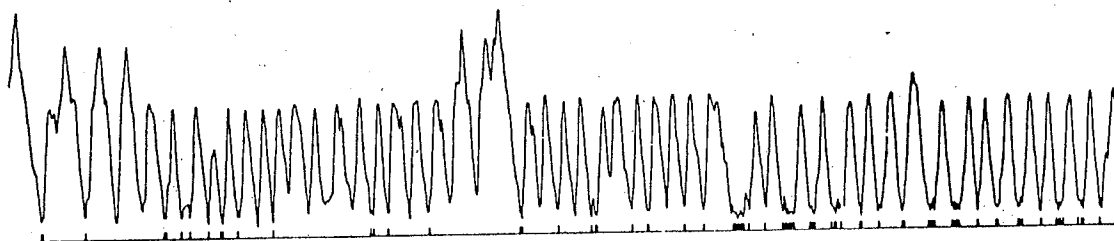
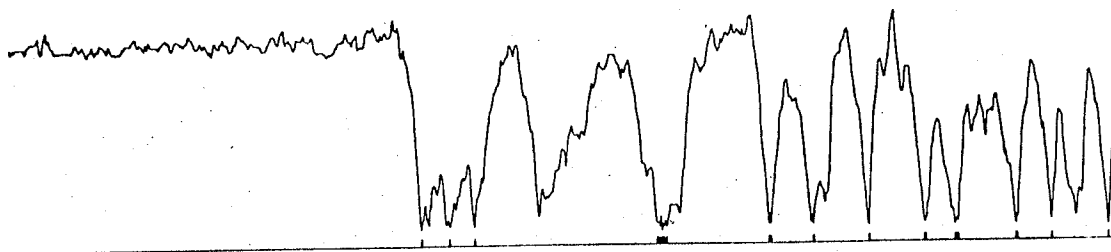
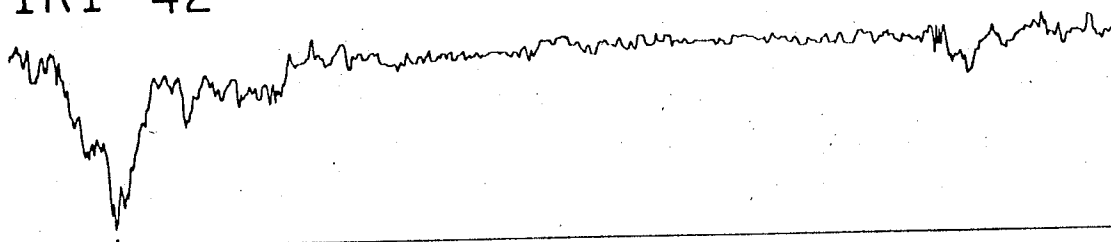
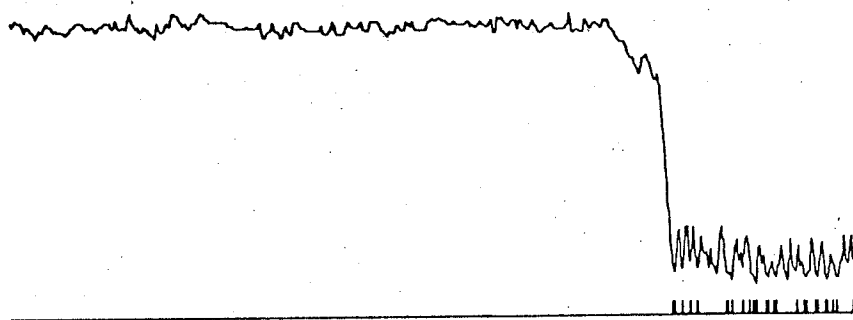


Figure 22. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 2-min Stage 5 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 2
Stage 5

P2A
IRI # 264



P2B
IRI # 183

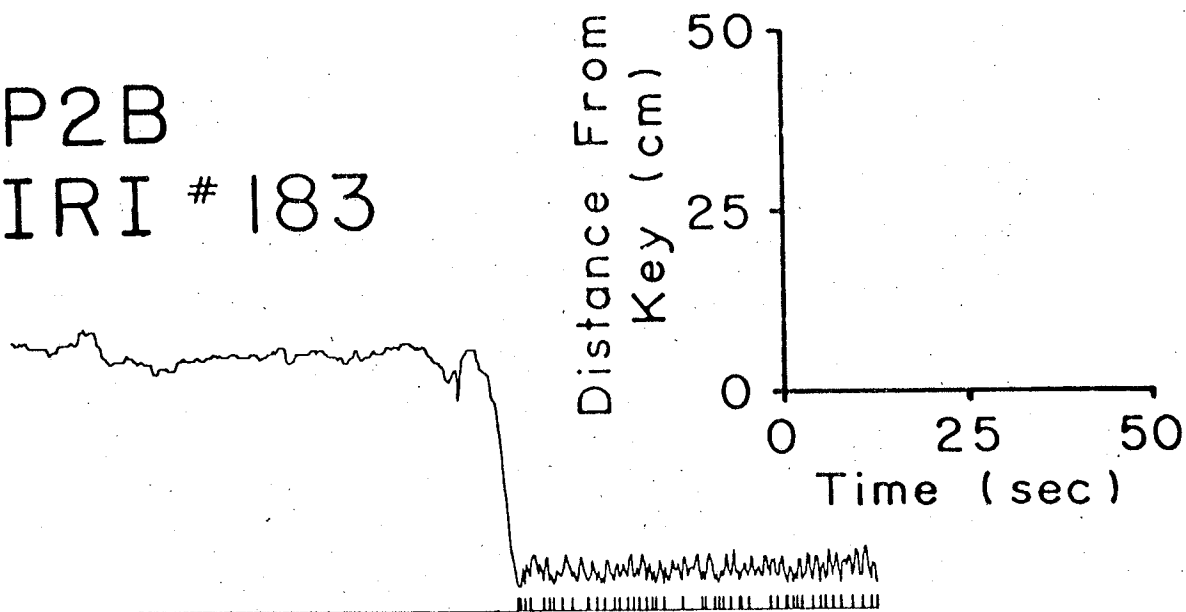
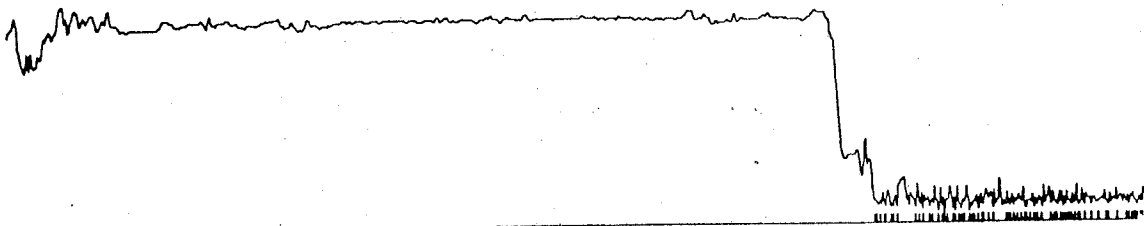


Figure 23. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 4-min Stage 5 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 4
Stage 5

P4A
IRI # 302



P4B
IRI # 295

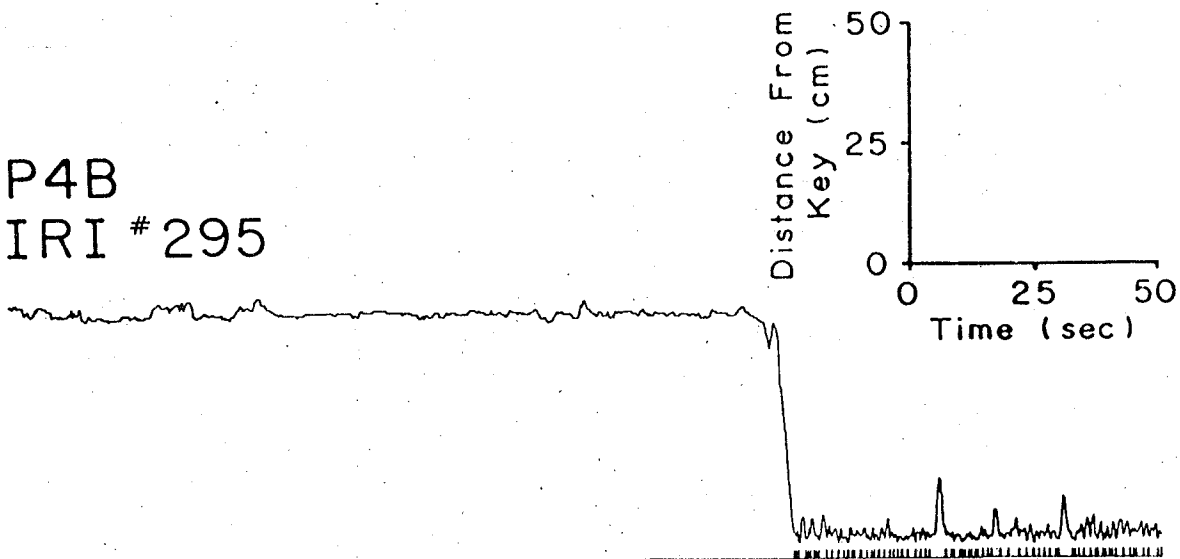
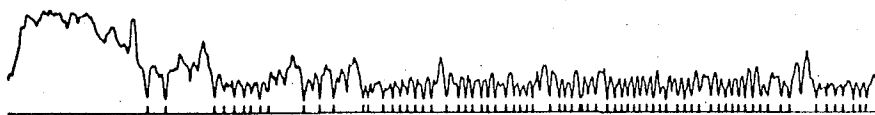


Figure 24. Selected IRIs showing distance from the region of the pigeon's head to the response key for FI 8-min Stage 5 performance. The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 8
Stage 5

P8A
IRI #84



P8B
IRI #380

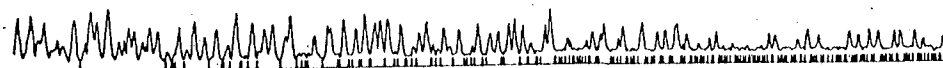
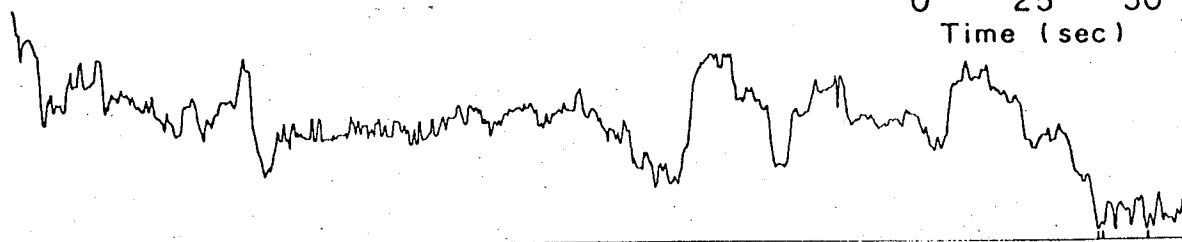
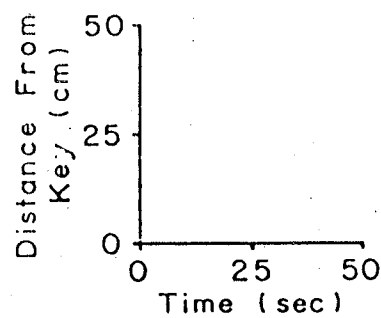


Figure 25. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 5 performance (P16A). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 16
Stage 5

PI6A
IRI * 120

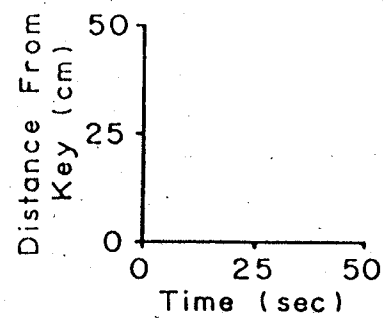
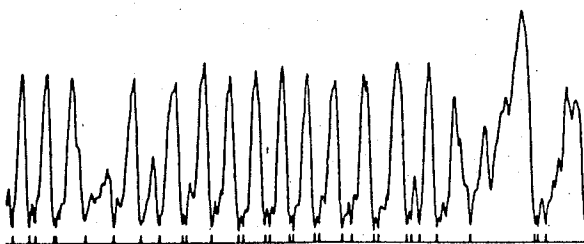
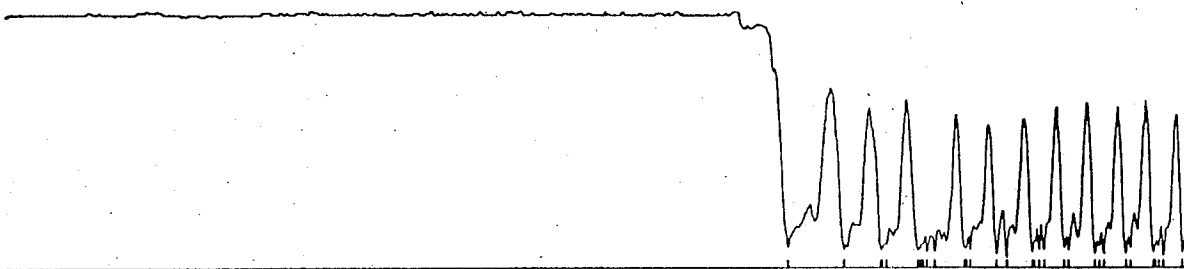
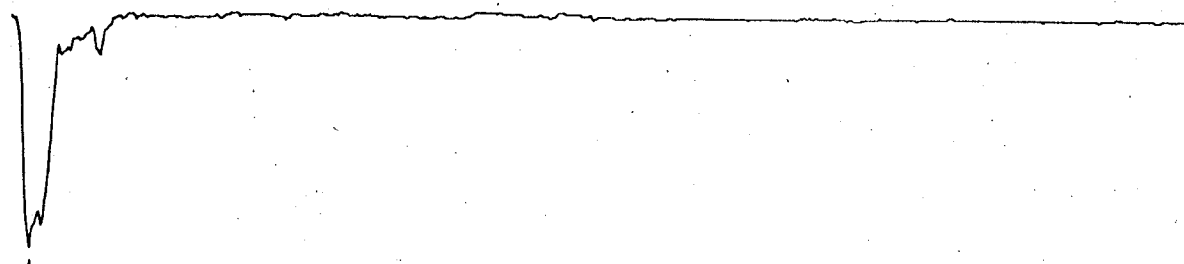


Figure 26. Selected IRI showing distance from the region of the pigeon's head to the response key for FI 16-min Stage 5 performance (P16B). The horizontal line indicates the position of the response key while the vertical slash marks on this line indicate when key pecks occurred.

FI 16
Stage 5

PI6B
IRI # 352

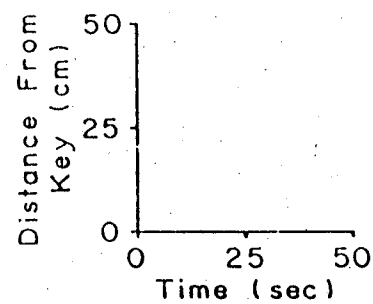
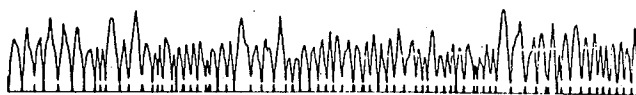
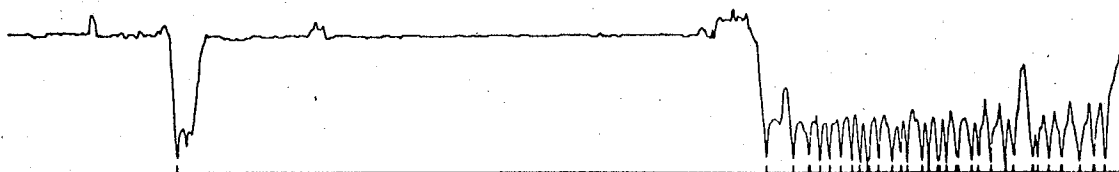
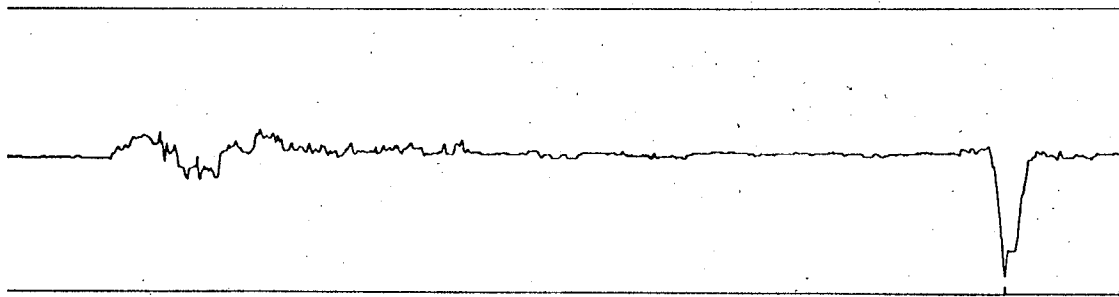


TABLE 1

Percent of key pecks in Figures 2 to 26 associated with low amplitude high frequency waves; i.e., amplitude ≤ 10 cm, period ≤ 5 sec.

(Numbers of key pecks examined are indicated in parenthesis)

		Stage					Total
		1	2	3	4	5	
		% (N=)	% (N=)	% (N=)	% (N=)	% (N=)	% (N=)
BIRD	16A	93 (54)	75 (102)	81 (165)	79 (224)	50 (68)	77 (613)
	16B	68 (41)	74 (159)	45 (77)	61 (110)	22 (121)	55 (588)
	8A	82 (33)	49 (79)	75 (81)	91 (148)	86 (79)	79 (420)
	8B	86 (29)	80 (122)	54 (48)	48 (54)	93 (188)	79 (441)
	4A	56 (9)	93 (69)	87 (53)	100 (28)	99 (68)	94 (287)
	4B	91 (35)	99 (80)	80 (59)	96 (93)	97 (79)	94 (346)
	2A	83 (106)	81 (32)	79 (47)	79 (38)	67 (27)	80 (250)
	2B	94 (33)	83 (42)	82 (39)	83 (48)	98 (49)	88 (211)

DISCUSSION

Figures 2 to 26 show that five response-rate patterns occurred within an IRI as FI behavior developed from early to late performance. These patterns were: (1) negative acceleration in rate within the IRI; (2) irregular moment-to-moment rate throughout the IRI; (3) a short PRP followed by irregular moment-to-moment rate; (4) positive acceleration in rate; and finally (5) long PRP followed by an abrupt change to a high constant rate. These rate patterns for FI schedules have been observed by others (eg., Ferster and Skinner, 1957), and thus it appears that the behavior examined in the present study represents typical FI performance.

The figures also indicate that each of the above response-rate patterns were associated with a specific behavior-wave pattern. Consequently, it might be argued that the behavior waves add little to our understanding of FI behavior or the key-pecking operant. One must consider, however, two important points. First, behavioral phenomena occur as FI behavior develops. When observing behavior as instantaneous events, one can only describe these phenomena in terms of instantaneous events. By monitoring behavior continuously, however, additional information is obtained. That some correlation exists between the behavior-wave patterns and response rate is therefore not surprising since the two types of observations are obtaining information concerning the same behavioral phenomena. However, the information derived from observing both behavior waves and response rate is more comprehensive than that obtained from observing response rate alone, since the behavior waves cannot be derived from response rate. Second, although one might infer a particular wave

form on the basis of IRT length (i.e., time between actual key pecks), Figures 2 to 26 indicate that similar IRT lengths can be associated with quite different wave forms depending on the stage of FI development. Thus, a change in wave form need not be reflected by a change in response rate. This is illustrated by the following three wave forms that occurred during pausing; i.e., when moment-to-moment rate of pecking was zero, at various stages throughout the development of FI behavior.

1. A pause in pecking can be associated with low amplitude high frequency waves occurring close to the response key. The bird is standing in one place and making head movements towards the key, but the movements come short of actually closing the switch. This pattern occurred during early FI performance (eg., see Figure 3, P4A) and has been observed by others following a large decrease in reinforcement frequency (Pear, Rector and Legris, in press).

2. A pause in pecking can be associated with high amplitude moderate frequency waves. The bird is walking from the key to the back of the chamber and then back to the key. This pattern can simply repeat itself (eg., see Figure 4, P8B) or change systematically depending on the stage of FI development (eg., see Figure 19, P8B).

3. A pause in pecking can be associated with high amplitude low frequency waves. The bird walks from the key to the back of the chamber and stays there for a relatively long period of time before approaching the key. The amount of time standing fairly still away from the key is reflected in the behavior wave as the duration of its peak. These waves typically occurred at the end of an IRI during early FI performance (eg., see Figure 3)

and during the PRP in late FI performance (eg., see Figure 22).

A pause in pecking can be associated with any one or a combination of the above three wave patterns. In summary, short IRTs (generally less than a few seconds) simply reflect short movements away from the key. Longer IRTs, however, were characterized by a variety of wave forms that occurred systematically within an IRI or throughout the development of FI performance. Thus, where the traditional measure of behavior showed an absence of an event over time; i.e., a zero response rate, the present technology was able to describe a variety of behavioral processes.

In addition to providing more information about the development of FI behavior, the findings of this experiment address a number of related theoretical issues.

The operant

Skinner (1969) stated, "An operant is a class of which a response is an instance or member ... It is always a response upon which a given reinforcement is contingent, but it is contingent upon properties which define membership in an operant. Thus a set of contingencies defines an operant." (p. 131).

Although members of an operant response class are typically viewed as instantaneous events, it has been the position of this paper that members of an operant class can be analyzed as movements consisting of behavioral elements, an approach originally adopted by Skinner in his earlier writings. There is no question concerning the value of the former approach in the development of our ability to predict and control behavior.

The value of the latter approach can be questioned, however, since the amount of data related to behavioral sequences in relation to the operant is limited.

In examining the above issue, some questions need be addressed. First, if we view the members of an operant as instantaneous events, are other behavioral events which occur important for analysis? Second, if these other events are important, what are some ways of organizing these behavioral events within a conceptual system? In relation to the first question, a reinforcement contingency affects behavior in a number of important ways. First, it may increase the frequency of a particular response class, and second, it may affect the frequency of other behaviors and how these other behaviors are distributed over time (Anderson and Shettleworth, 1977; Falk, 1971; Shettleworth, 1975; Staddon, 1977). In the present experiment, examining behaviors in addition to key closures resulted in a description of behavioral processes occurring during FI schedules that could not be derived from examining key closures alone. Therefore, from the point of view of predicting behavior it appears that the behaviors other than the switch closures are important for analysis. To what extent these other behaviors need be analyzed will depend on the types of questions addressed by the experimenter and the types of functional relationships obtained. What is more debatable, and cannot be determined from the present experimental results, is the best way to conceptualize those behaviors that are not actual switch closures. Even if behaviors other than key closures are recognized as important, one may still view

the operant as a class of instantaneous events each possessing the property upon which reinforcers are contingent, with all other behavioral events as members of other behavioral units. The present position is that a variety of behavioral units can be identified, but the operant can consist of functionally related elements that do not necessarily possess the property upon which reinforcers are contingent (Catania, 1973a). Arguments for the former position are the years of research and applications that have demonstrated that positions ability to predict and control behavior. In terms of a data base, arguments for the latter approach are considerably weaker. The position of this author, however, is that the latter approach appears to be a feasible approach to the organization of our data that needs to be explored further before it is either adopted or rejected.

Constituents of response rate

As outlined in the introduction, when the operant is viewed as a behavioral sequence two variables may affect response rate as typically measured: (1) the amount of time allocated to the operant; and (2) the spatial character of the operant. Changes in response rate as a function of time allocated to the operant have been well documented (Crowley, 1979; Gilbert, 1958; LaBounty and Reynolds, 1973; Rand, 1977), while structural changes in the operant affecting response rate have not been well documented (but see Skinner, 1957; Pear and Rector, 1979).

In the present study response rate varied within an IRI and throughout the development of FI behavior. The changes observed in the behavior waves suggest that both of the above changes occurred and affected response rate.

Changes in time allocated to key pecking, however, appear to account for many of the changes observed in response rate, especially for the FI 2 and FI 4 schedules. This interpretation is based on the observation that for these schedules periods of pecking were associated with structurally similar behavior waves; i.e., low amplitude high frequency waves (see Table 1). Generally, lengthy periods of nonpecking were characterized by high amplitude waves of either moderate or low frequency. Changes in response rate were reflected by changes in the frequency of occurrence of the low amplitude waves occurring close to the key; i.e., in the amount of time allocated to the key-pecking activity.

From a structural point of view the data also suggest that systematic structural changes in the operant can occur and affect response rate. This interpretation of the data is based on the observation that although there usually was a predominant wave form associated with pecks across all stages of the development of FI behavior, this was not the case for FI 16 (see Table 1). It is therefore possible for one wave form associated with pecks to decrease in frequency while another increases, thus affecting response rate as typically measured. It should also be noted that although the same wave form was predominantly associated with pecks for the FI 2, FI 4, and FI 8 schedules, at present it would be an overgeneralization to argue that this was a common feature of pecking for these schedules. The schedule of reinforcement may not be the only variable affecting response form. Possibly other variables held constant in this experiment, such as level of food deprivation or type of reinforcer (cf. Jenkins and Moore, 1973), may affect the predominant wave form regardless of the schedule of reinforcement.

The above interpretation represents a structural analysis of the data in that it views the wave form associated with pecks as reflecting the occurrence of the operant unit. A functional interpretation of the data is that the wave form associated with pecks may not reflect the key-pecking operant, but rather a set of related operants such as turning and approaching the key. Therefore, the predominant wave form associated with pecks may have changed, not because the structure of the key-pecking operant changed, but rather because the frequency of occurrence of a variety of operants changed systematically, thus affecting the wave form predominantly associated with key pecks.

Regardless of which of the above interpretations, if either, is more valid, it is clearly not possible to identify separate activities by examining only their structures, since their controlling variables must also be determined (Skinner, 1969). Future research, however, may fruitfully examine these issues by combining the spatial-structural technique of the present study with the temporal-structural technique of other researchers. For example, Anderson and Shettleworth (1977), Staddon and Simmelhag (1971), Shettleworth (1975), and Wong (1977, 1978) defined behavior classes and determined the amount of time these classes were engaged in within an IRI. By combining the latter technique with the present spatial analysis it would be possible to not only determine the amount of time each behavior class was engaged in, but also describe those systematic changes that may occur within each class and the transitions that occur between classes. To summarize, one direction for future researchers is to determine if or when systematic changes in wave forms reflect systematic changes in the structure of a response class, or systematic changes in the frequencies of a group of related response classes.

Based on the present data, conclusions concerning the structure of the operant unit and changes in the constituents of response rate are speculative. The present data are clear, however, in showing how behavior waves change systematically within an IRI and throughout the development of FI behavior. What variable or variables could produce these systematic changes will now be discussed.

Stimulus control and interim activities

"Stimulus control is observed when a change in a particular property of a stimulus produces a change in some response characteristic (Rilling, 1977)". The presentation of a conditioned stimulus that results in a decrease in response strength is referred to as an inhibitory stimulus. A conditioned stimulus that increases response strength, relative to its absence, is referred to as an excitatory stimulus. Changes in response strength following a change in a stimulus class have been measured by: (1) response rate changes (Guttman and Kalish, 1956; Jenkins and Harrison, 1962); (2) IRT changes (Blough, 1963, 1969); and (3) time engaging in the experimental operant (Migler and Millenson, 1969; Rand, 1977). An analysis of behavior waves should also prove to be useful in providing a more comprehensive analysis of the behavioral changes following a change in a stimulus class. The present data may in fact provide us with information concerning these changes.

During steady-state FI performance, the "break-run" pattern of pecking can be considered to be the result of a discrimination between an "extinction" (S^-) component and a "variable-interval" reinforced (S^+) component (Schneider, 1969), with the discriminative stimuli possibly being temporal.

This analysis is supported by Wilkie (1974) who obtained inhibitory stimulus control gradients during the early portion of an IRI, but excitatory gradients during the latter portion of an IRI. In the present experiment, steady-state FI (Stage 5) was characterized by a flat "wave" occurring a considerable distance from the key, followed by an abrupt change to low amplitude high frequency waves associated with key pecks. Due to the presence of two distinct waves or states, the data tends to support earlier conclusions (Migler and Millenson, 1969; Rand, 1977) that the presentation of an inhibitory or excitatory stimulus simply decreases or increases the amount of time engaging in the experimental operant, respectively.

The present data also provide a description of the continuous behavioral changes that occur while the discrimination exhibited during steady-state is developing in earlier FI stages. For example, Stage 4 was characterized by positive acceleration in pecking rate within the IRI, thus reflecting an intermediate stage in the development of the discrimination described by Schneider. During this stage, behavior waves changed systematically within the IRI. Following the flat "wave" at the start of the interval, one observes a fairly gradual change from high amplitude waves to low amplitude high frequency waves. Nondefining approaches associated with both types of waves tended to occur during the middle portion of the IRI. What appears to be occurring therefore are systematic changes in behavior; i.e., oscillations between pecking and not pecking, as a function of a gradual change from inhibitory to excitatory stimulus control within the IRI.

The change in stimulus control that is known to occur across the IRI of FI schedules provides support for the hypothesis that some of the waves observed in the present data reflect the occurrence of interim activities. Depending on the species examined, observations of steady-state performance in periodic food schedules (response-dependent and response-independent) has shown that during S^- periods activities such as drinking, wing flapping, and aggressive behaviors occur at a frequency higher than that observed prior to conditioning sessions (see Staddon, 1977, for a review). These scheduled-induced behaviors have been termed interim activities. Staddon and Simmelhag (1971) proposed that interim activities serve the adaptive functioning of removing the animal from food situations at times when food delivery is unlikely; i.e., during S^- periods. It is therefore possible that in the present study the high amplitude waves, resulting from the bird moving a considerable distance away from the key, represent the occurrence of interim activities during S^- periods. The systematic changes observed in the high amplitude waves as FI performance developed may therefore reflect systematic changes in interim activities as stimulus control developed within the IRIs.

An alternative explanation for the high amplitude waves is that they reflect the occurrence of a complex set of operants related to the key-pecking operant (Skinner, personal communication). The response key, the pecking of which is followed by food, may have become a conditioned reinforcer. Therefore turning, approaching the key, and positioning the head may have been response classes reinforced by either the presentation

of the key or increased proximity to the key. A wave may therefore reflect the occurrence of a set of operants. This interpretation, however, is not necessarily incompatible with the previous interpretation of high amplitude waves. As stated earlier, it has been demonstrated that for FI schedules there are S^- periods. Thus, for FI schedules the key may not always function as a conditioned reinforcer. When the key functions as an inhibitory stimulus (Wilkie, 1974) the animal may be removing himself from the inhibitory stimulus (Staddon and Simmelhag, 1971). When the key later functions as an excitatory stimulus, the operant-chain process suggested by Skinner above may take affect. Future research might therefore differentiate between those variables or stimulus conditions that affect movements away from the key versus those variables or stimulus conditions that affect movements towards the key.

Summary comments

The frequency and amplitude of behavior waves changed systematically within an IRI and across the development of FI performance. Five behavior-wave patterns were identified to describe this developmental process. The predominant wave form associated with key pecks remained fairly constant for FI 2 and FI 4, showed some unsystematic changes for FI 8, and changed systematically for FI 16 when comparing early performance with steady-state performance.

Interpretations of the above findings address a variety of related theoretical issues in the experimental analysis of behavior. First, a reinforcement contingency increases the frequency of certain behavioral

elements in addition to those elements that possess the property upon which reinforcers are contingent. One issue for future research is whether or not these functionally related elements, and consequently behavior sequences, should be incorporated into the definition of the operant. Second, since extensive nonpecking periods were associated with high amplitude waves, and since no one predominant wave form was associated with key pecks, the data suggest that for FI schedules changes in moment-to-moment response rate may reflect either a change in the proportion of time key pecking or a change in the structure of the pecking activity. Future research might combine the spatial-structural analysis of the present study with the temporal-structural analysis of others (eg., Staddon and Simmelhag, 1971; Shettleworth, 1975) to provide a more comprehensive analysis of how the constituents of response rate vary over time. Third, the high amplitude waves observed during nonpecking periods may reflect the occurrence of interim activities. The changes observed in these waves throughout the development of FI behavior appear to reflect the development of inhibitory and excitatory stimulus control within an IRI. Finally, the present data suggest the importance of both a structural and functional approach to the analysis of behavior. On the one hand, the behavior waves of the present study provided important information about the development of FI behavior that could not be derived from examining instantaneous members of a response class almost free of structure. On the other hand, different wave forms need not reflect different behavioral units, and similar wave forms need not reflect the occurrence of one particular behavioral unit. In general, the controlling variable of a

response cannot be determined by examining the structure of the response. Thus, depending on the type of questions an experimenter addresses, behavior researchers may have to incorporate into their analysis some of both the structural and functional aspects of behavior.

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