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# BEHAVIOURAL VARIATION IN EXTENDED AND ALTERNATING EXTINCTION

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### Abstract

Hens were trained to peck a square stimulus on a touch-sensitive screen under an FR5 reinforcement schedule for a maximum of 30 reinforcers (taking approximately 10 minutes). Then hens experienced extinction sessions of 40 minutes duration. For a total of six conditions, reinforcement and extinction conditions were alternated. Each condition consisted of between approximately 7 and 10 sessions. Results show that structures developed during conditioning remain in extinction, at least for the duration of previous reinforcement sessions. After approximately 10 minutes, behaviour becomes more variable. There was also an absence of any 'extinction burst'. Extended extinction conditions, and alternating extinction conditions with reinforcement conditions had little effect on the variability of behaviour, but did influence the rate of responding. Responding persisted a little longer before gradually declining across sessions in the first extinction condition. In extinction conditions 2 and 3 responding tended to occur more as 'peaks'; short periods of increased responding with periods of non-responding between peaks.

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## Introduction

Extinction is defined as “The procedure of withholding reinforcement for a previously reinforced response...” (Pierce & Cheney, 2004, p. 100). Extinction can also refer to the behavioural process, which includes “...a decline in the rate of response caused by withdrawal of reinforcement.” (Pierce & Cheney, 2004, p. 100). Behaviour during an extinction procedure declines in frequency, and after a period of non-responding, that behaviour then may be said to have become ‘extinct’. In the current study, extinction is defined as a procedure which includes the withdrawal of reinforcement from a previously reinforced response.

Behaviour can show variability over different dimensions of a response. Studies on behavioural variability in extinction have included dimensions such as force, duration and location. Notterman (1959) measured the variation of response force of the lever press. In this experiment, rats were required to press a lever for access to food. Force magnitude and the amount of variation in magnitude across responses were recorded during both conditioning (a continuous reinforcement (CRF) schedule) and extinction. During conditioning both the overall magnitude of forces, and variation of forces, reduced. In other words, responses became more stereotypical (Notterman, 1959). In extinction, the overall force magnitude had increased when compared to the overall force magnitude from reinforcement sessions, and the amount of variation in the forces produced also increased. An experiment by Crow (1978) again with rats and the lever press response, measured response durations during CRF and extinction. This study found that even over very short extinction periods (three 1 minute extinction segments were presented within a 30 minute ‘extinction’ session), variation in response duration increased in extinction when compared to the variation that was present in CRF. The above studies provided support for the argument that in extinction variability increases (and in reinforcement variability decreases), and this increase in variability appears to occur across many dimensions of the response, such as force and duration mentioned here.



Antonitis (1951) was the first of only a few studies to look at variability of response location in extinction compared to a CRF schedule of reinforcement. In this study, rats were required to poke their nose through a 50cm long response slot in order to obtain a food pellet. Antonitis found during the continuous reinforcement (CRF) schedule, variation in response location decreased, responses becoming more stereotypical, and during the extinction procedure, response variability greatly increased. This study again provides support for the argument that variation decreases during reinforcement, and increases in extinction; this time on the dimension of location, of which is most relevant to the current study.

While the above studies found variability increases in extinction when compared to reinforcement, these studies have compared only the extremes in terms of contingencies. These studies have observed the effects of a period of continuous reinforcement followed by a period of no reinforcement, on behavioural variation. During CRF behaviour becomes more stereotypical, and in extinction, behaviour becomes more variable. In CRF sessions, every response is reinforced, while in extinction, no responses are reinforced. A CRF schedule and an extinction procedure appear to be at opposite ends of a contingency continuum (noting that in extinction, there is actually no contingency). If stereotypy is observed during CRF, and variability is observed during extinction, then it can be assumed that at other values of reinforcer intermittency (along this continuum) behavioural variation will increase as the intermittency of reinforcement reaches a state where responses are no longer reinforced. In other words, because intermittent reinforcement schedules more closely resemble extinction than a continuous schedule, increased behavioural variation should present (Eckerman & Lanson, 1969). This theory was tested by Herrnstein (1961), in a similar study to that of Antonitis (1951). Herrnstein studied response locations of pigeons first under a CRF schedule and then under an intermittent, VI 3min schedule. Herrnstein (1961) reported responses became more stereotypical in the VI 3min schedule than in the CRF. These results are contrary to the above theory, yet when replicated by Eckerman and Lanson (1969) in Experiment three, results were in agreement with the above theory. The study by

Eckerman and Lanson (1969), in different experiments, was a replication of both the Antonitis (1951) and the Herrnstein (1961) studies, using pigeons and a response strip. In the Eckerman & Lanson (1969) study, variation increased during extinction as compared to CRF, and variation also increased in the VI 3min schedule compared to CRF, contrary to the results of Herrnstein (1961).

In Experiment 2, by Eckerman & Lanson (1969), variability was observed under various interval schedules. Pigeons (the same subjects used in Experiment 1) received 100 reinforcements under CRF for 5 sessions, then 100 reinforcements under a fixed-interval (FI) 15-sec schedule, and then various random interval (RI) sessions. In these RI's, the probability of reinforcement for the first response in any 15-sec interval, of which each schedule continued for a total of 33 reinforcers, ranged from 0.1 (equivalent to a 150-sec FI schedule), to a probability of 1 (equivalent to a 15-sec FI interval schedule). The conclusion of this experiment was that variability increases in intermittent reinforcement. The Eckerman & Lanson (1969) study provides support for the idea that in extinction, which is at the extreme end of a contingency continuum, variation increases. This study also provides support for the idea that in intermittent reinforcement, variability increases. An intermittent reinforcement schedule closer to extinction than to CRF (the other extreme end of the contingency continuum), and behaviour under intermittent reinforcement was found to have more response variation than that observed during CRF.

A study by Boren, Moerschbaeche & Whyte (1978) looked at variation in responding during fixed-interval (FI) and fixed-ratio (FR) reinforcement schedules; different types of intermittent schedules. In this study, six levers, spaced 7cm apart, were arranged into a horizontal strip. A response on any of these response levers were counted toward a reinforcement, which when available, was singled by a tone and the onset of red lights above two reinforcement levers. The reinforcement levers were located directly below the response levers, one giving access to water and the other giving access to food (so long as reinforcer availability was being

signalled). Subjects were two rhesus monkeys who responded first under various FR schedules, then under various FI schedules. The FI schedule was arranged so that the frequency of reinforcers approximately equalled that received in its matching FR schedule. That is, the mean reinforcement frequency for a FR ratio was calculated and an interval value was assigned to give approximately the same frequency of reinforcers for the FI schedule as was received in the FR schedule. Variability was measured by the number of switches between levers, or the number of responses on the same lever. In general and for both subjects, switches between levers were more frequent (variability was higher) in FI schedules and especially at larger FI values, while all FR schedules (except FR1) produced 100 percent stereotypy (i.e. no switching between levers throughout the session). This study is interesting because here one intermittent schedule was shown to produce high stereotypy compared to CRF (or FR1), while the other intermittent schedule was shown to produce high variability. The key factor therefore must be the response requirement (being high in an FR, and low in an FI), and that on an FR schedule, intermittency of reinforcement is partially determined by rate of responding. This effect reflects the idea that many responses on one lever will be more energy efficient than responding across levers when the response requirement is high (Boren et al., 1978), therefore explaining the increased variation in the CRF compared to the, intermittent, FR schedule. Intermittent schedules with low response requirements should then result in low rate responding and increased variability.

A theory proposed by Neuringer (1991) was that perhaps inherit in low rate responding was increased variability. This idea is consistent with the observed increase in variability seen during low response rates under the FI schedule in the above experiment by Boren et al., (1978). In the Experiment 1 by Neruinger (1991), a response pattern consisted of four responses across two levers, which was reinforced so long as the lag 5 variability criterion was met. This lag criterion meant that a total of six different response patterns (in succession) were required before reinforcement became available. So if a rat pressed the left lever twice, then the

right lever twice, this equalled one pattern. To meet the variability criterion, the rat would then need to produce another four responses across the two levers that were different to the previous pattern. This would then be repeated until a total of six different patterns had been made, after which, reinforcement was obtained. During this experiment response rates were slowed through the addition of inter-response-intervals (IRI's) meaning that each response was separated from the following response by a pre-selected interval. All IRI's darkened the houselight, signalling responses at that time to be ineffective, and any response that did occur within the last 0.5s of the IRI reset the interval. Seven IRI's ranging from 0 to 4 seconds, were presented in a semi-random order. Each IRI was in effect for five sessions. Results show that response variability increased with increasing IRI time, in agreement with the idea that possibly inherent in slow rate responding is increased variability.

A second experiment also by Neuringer (1991) compared two groups, a 'vary' and a 'repetition' group. For the 'vary' group, the experiment was a repetition of that described in Experiment 1, except for the IRI values. For both 'vary' and 'repetition' groups, session IRI's ranged from 0 to 20 seconds, not presented in ascending order, although the 20 second IRI was presented last. Repetitions of one pattern only were reinforced for the 'repetition' group, while variations were again reinforced for the 'vary' group. The percentage of correct pattern occurrences (and the response rate) decreased as the IRI's increased for the repetition group, while percent correct for the vary group improved. Results from Experiment 1 and 2 of Neuringer (1991) indicate that while reinforcement may be contingent on repeating a particular response pattern, increasing the time between responses disrupt this; responses become more variable and reinforcement therefore less frequent. Increasing the time between responses will increase the frequency of reinforcement though, if behaving variably is the reinforcement contingency. Some evidence for a relation between slow rate responding and increased variability is supported in another study by Neuringer, Kornell & Olufs (2001) where longer trial durations tended to have increased variability in Experiment 1 and 2. Also, referring

back to the Herrnstein (1961) study, high stereotypy was observed during the intermittent VI-3min schedule compared to the CRF schedule, but also, as noted by Eckerman & Lanson (1969), response rates had increased in the VI-3min schedule. The rate of responding in extinction conditions therefore should be carefully examined, as it would need to be determined if variability results from slow rate responding or the extinction procedure itself.

The experiments by Neuringer, Kornell & Olfus (2001) also support an idea that structures developed during conditioning remain in extinction. In the study by Neuringer, Kornell & Olfus (2001), patterns, and frequencies of each pattern were recorded during reinforcement and extinction conditions. During reinforcement, rats were required to create variable sequences across two levers and a key, each sequence required three responses and for reinforcement to become available, sequences had to meet a variability criterion. During extinction, as response rates reduced variability increased, yet the overall structure (relative frequencies of sequences emitted) remained very similar to that seen in conditioning. Also, while the same structure remained, there was some increased variability in extinction as a result of slightly increased occurrences of the least frequent sequences (relative to other sequences, i.e. this was not enough to change overall hierarchy of sequences emitted). The second experiment confirmed this again; in extinction, variability increased while structures remained, although in this example, variable responding was not required during reinforcement.

Other studies have similar results. If structures seen in conditioning remain in extinction, then discriminations learned in conditioning should remain present in extinction (i.e. the task is not 'forgotten'). Nevin (1967), Experiment 1, found in a simultaneous discrimination task, that the performance of pigeons not only remained intact, but improved after extinction. In this experiment, pigeons were required to peck the brighter of two lit keys to receive reinforcement under the current random-trial (RT) schedule. After extinction, the probability of responding was slightly higher than before extinction, and also the probability of responding

correctly had increased. During extinction, the probability of responding declined yet the probability of responding correctly remained stable across the ten extinction sessions. Pigeons maintained their discrimination performance in extinction, despite not being reinforced for doing so, in other words, structures (and therefore learning) remained in extinction.

Goldberg (1959) in a study of rats and force of the lever press found that the hierarchy of response forces seen in extinction was very similar to the hierarchy observed during reinforcement. There were some differences however. In extinction the hierarchy remains although the low frequency forces have increased and the high frequency forces have decreased slightly, when comparing reinforcement with the following extinction. The theory that structures seen in reinforcement remain in extinction is also supported for duration variations of the lever press response in a study by Margulies (1961). Rats were required to press a lever with a minimum force of 6 gm in order to receive reinforcement, on a CRF schedule, and then were placed in extinction after a pre-determined number of reinforcements. The hierarchy of durations seen in reinforcement also remained present during extinction, similar to the findings of Goldberg (1959), mentioned above. There were with this study also, some slight differences in the frequency distributions of responses between extinction and reinforcement conditions. Lever presses of long durations reduced in frequency across reinforcement sessions, and these long durations again increased in frequency during extinction sessions. The reduction in frequency of long lever press durations during reinforcement indicates a reduction in duration variation across reinforcement sessions, which then increased in extinction. So from these few studies there seems to be strong evidence for only a slight increase in variability, but overall, the same structure of responding seen during reinforcement remains in extinction.

The studies of response location mentioned earlier (Antonitis, 1951; Eckerman & Lanson, 1969) concluded that variability increased in extinction. In the Antonitis, (1951) study, it is stated that frequency distributions of responses were very

different when comparing extinction and operant level responding to conditioning distributions. Eckerman & Lanson (1969) also observed changes in the distributions of responses along the length of the response strip. According to Figure 2, pg. 76 of Eckerman & Lanson (1969), only for one bird did the distribution of responses seen in conditioning remain similar to what was seen in extinction. For the two other birds, response distributions varied greatly in extinction. These findings are in opposition with the findings of both the Goldberg (1959) study and the Margulies (1961) study, as these studies show that while there is an overall remaining structure, that is, a hierarchy of responses, some variation of this structure does occur between reinforcement and extinction conditions. The studies of Antonitis (1951) and Eckerman & Lanson (1969) on the other hand suggest overall structures are quite different when comparing conditioning with extinction.

So far this thesis has discussed schedules of reinforcement and extinction in relation to the effects on the variability of the measured response dimension (such as duration, rate, and location). The next section of this thesis will discuss effects of extended extinction and the effects of alternating extinction and reinforcement conditions on the variability of behaviour, as well as some more general effects of extinction.

Only a few studies have analysed the effects of extended extinctions (that is, many extinction sessions) on response rate and variation. The study by Nevin (1967) discussed above has an extinction condition ten sessions long before returning to conditioning. Responses declined across the extinction sessions although the probability of responding correctly remained comparatively stable. The effect of extended extinctions has also been examined by Anger & Anger (1976). In this study pigeons were autoshaped to peck a key stimulus five times in phase one before immediately moving onto phase two in which one peck of the lit key resulted in access to grain and the key light going out. Trials consisted of a total of 26 seconds where if no pecks were made the key remained lit for 16 seconds, then off for 10 seconds, if a peck was made, the key light went out (for the remainder of the 26

second cycle) and reinforcement immediately followed. The session ended after 10 reinforcements. In the following session, phase three, the same schedule from phase two was used with two differences; the schedule for reinforcement was now a variable-ratio (VR) schedule beginning at VR1 and gradually increasing to VR5, and a session ended after 45 reinforcements and 100 first responses. The next phase was extinction for a total of eight sessions with each session consisting of 100 trials. Phases 1 through to extinction were repeated exactly at least eight times, resulting in two days of reinforcement between each eight day extinction series. Focusing on their non-colour change subject results, it can be clearly seen that day 1 of the first four repeated extinction series has response rates higher than all others. This response rate, from day 1, decreases across series. After the first four series, day 1 values are no different to any other day. Day 2 across each series appeared to have, by a slight number, the lowest mean number of responses, which was a large reduction compared to day 1 values over the first three series. For days 3 to 8, the mean number of responses remained stable around low values. In simple words, after some experience of extinction series, birds learn to discriminate an extinction session on the first day of an extinction series. This is reflected with the mean number of responses at day 1 being approximately equal to the mean number of responses at day 8, as was seen in later extinction series (Anger & Anger, 1976). Currently there are no studies looking at the effect of extended extinction on the variability of response location.

The results from the Anger & Anger (1976) study suggest that after some experience with alternating many successive extinction sessions with two days of reinforcement, behaviour (at least in terms of median number of responses) is no different on day 1 as any other day in an extinction series. Similar findings appear in the case of alternating extinctions. For example, a study by Wickens & Miles (1954) alternated one hour of conditioning with one hour of extinction thirty times. The subjects were rats who pressed a bar in order to receive food reinforcement. Reinforcement sessions lasted for a maximum of 15 reinforcements or one hour, extinction sessions were one hour. Results show the number of responses in



extinction sessions quickly increased across the first three sessions before quickly, and then gradually, reducing until a low but stable response rate was reached at about session 19. This resulted in extinction sessions 19 to 30 appearing no different in terms of the median number of responses made. This reduced response rate in extinction at later sessions was shown not to be a result of learned discrimination between the conditions, but most likely a discrimination between reinforced and non-reinforced responses (Wickens & Miles, 1954). These studies suggest that learning occurs with each experience of extinction, so that after some experience at extinction, median number of responses across any day of an extinction series is no different to any other day. These studies also suggest responses are very persistent in extinction.

It is often stated that with the onset of extinction, a burst of high intensity and increased rate of responding as well as increased variability will result (for example; Notterman & Mintz, 1965, Ch.3; Novak & Pelaez, 2004, Ch.6), before declining gradually over the course of the extinction session. Yet not all studies show this as was pointed out in the study by Bullock & Smith (1953). In their study, rats pressed a lever in order to gain food reinforcement under a CRF schedule for a total of 40 reinforcers. They then (beginning at response 41) experienced a one hour period of extinction. Extinction and reinforcement sessions were alternated ten times. Across reinforcement sessions, response rate increased, so that response rate in session 10 was much higher than in session 1, with the largest increase in response rates seen between sessions 1 and 2. In the first five minutes of the first extinction session, response rates decreased to about half that seen during the five minutes of reinforcement. Thereafter, response rate continued to reduce over the session. For all extinction sessions, response rates were always higher in the initial five minutes of the session (although this was still lower than the rate seen during reinforcement sessions), and then reduced to a low value for the remaining session time. This suggests there was no initial increase in response rate, or 'burst', which is otherwise expected, instead, responses decreased early in the extinction session and then

continued to decrease, to then remain stable at low rates. This suggests further examination of response rates in extinction is required.

A shortcoming from the majority of the above studies is the tendency to only focus on the end result; on only the overall effects that extinction sessions have on response rate and variation. In some studies (for example; McSweeney, Murphy, & Kowal, 2004; Bullock & Smith, 1953), within session responses have been recorded, but have been grouped with other individuals in the study, so that the finer details provided by individuals is obscured. What happens within an extinction session and to individual subjects is relatively unstudied, this lack of study being recognised by Tonneau, Ortiz, Cabrera, (2000). In their study, rats were required to press a lever for access to water. First conditioning was done under a VI 60s schedule, and then early session responding in extinction was evaluated from two test session types presented twice to the rats. Test sessions consisted of either 20 minutes reinforcement followed by 30 minutes of extinction, or 30 minutes of extinction followed by 20 minutes of reinforcement. It is interesting that no large or previously unseen response increase was observed at the onset of extinction when extinction began after 20 minutes of reinforcement. For most rats, response rates began at the level observed in the last few minutes of reinforcement, and then declined. In the extinction portion of test sessions, response rate began either at or below rates seen during conditioning. Response rates then reduced across the extinction portion of the session, and increased when reinforcement was again reinstated. In summing up this study; in the sessions beginning with extinction, there was no observed 'burst' of responding; another study with results contrary to common knowledge.

What is also interesting about the study by Tonneau, et al., (2000), was the observed changes in response rate that were recorded within reinforcement sessions. During conditioning often for approximately the first 10 minutes of the session, the rate of responding gradually increased. This same trend, although of lesser intensity, was seen during the first 10 minutes of test sessions when

extinction came first. This trend was also seen in test sessions where reinforcement followed extinction. In other words, extinction had little effect on following reinforcement rates of responding. In tests sessions, it was also noted that while the general trend was a decline in response rate across the extinction portion, there were 'peaks' of increased response rates within this general downward slope. Most studies give results as an overall session effect which may omit useful information from within an extinction session, as the above study has shown with reference to response rate during extinction. The results of the Tonneau, et al., (2000) study highlights the importance of analysing results from within both reinforcement and extinction sessions; these results giving a rich picture of how behaviour changes within sessions.

Within session effects on response variability were observed in the study by Antonitis (1951). During conditioning sessions, variability was seen to decrease across the session, to then increase at the start of the following session. Across reconditioning sessions, variability within the session was seen to decline at a faster rate than was seen in initial conditioning sessions. Variability within extinction sessions was not assessed. The only other known study to observe within session effects of extinction on behavioural variability was by Eckerman & Lanson (1969), their study finding no consistent trends within sessions.

The previous studies have observed the variation of responding along either a response strip/slot, as durations of lever presses, as forces of lever presses, or as response sequences. There are no known studies that have looked at the variation in responding outside of the response strip or slot, or outside of the reinforced lever press durations or forces. One aim of the current study is to observe responses that occur outside the stimulus area. To equate this with previous studies, this would be like observing pecks around the key as well as on it, observing lever presses of all forces and durations rather than forces or durations within a set range, or recording nose pokes or pecks that occur outside of a response strip or slot. This has not previously been done, and therefore there is no knowledge of how

responses that occur outside of the stimulus, or outside of the effective region, change as a consequence of changing contingencies. This means the level of responses outside of the effective or stimulus region is not known; for example, are there many responses that occur outside a stimulus region or any at all? Do these responses vary in the same way as responses that occur within the stimulus?

According to an article written by Catania (1973) responses occur along a continuum. For example, if a specific force range is reinforced in a lever press experiment, then it should be expected that forces outside but close to this range will also occur, despite their never being reinforced (Catania, 1973). Forces within the reinforced range (the effective region) should be most frequent, with forces slightly outside this range being less frequent. The distribution of responses should therefore look similar to a bell shape with the peak centred within the reinforced force region (Catania, 1973). The diameter of the bell shape is representative of the response continuum. In the current experiment, a square stimulus centred on a touch-sensitive screen is presented to hens. Under an FR5 schedule, pecks to this effective square stimulus region result in reinforcement, and pecks outside this effective region do not result in reinforcement and these pecks are also recorded. The main aim of the current study is to observe the occurrences and changes in the frequencies and patterns of pecks that occur both inside and outside the effective stimulus region. In other words, to observe the variation in peck responses and how they change in relation to changing conditions; in particular, extinction. Also, the current study attempts to examine the effects of alternating, extended extinctions on the variability of behaviour, across the dimension of location. Following the structure of the Antonitis (1951) study, a series of conditioning sessions are followed by a series of extinction sessions, repeated three times.

It is hypothesised that in extinction responses should vary more than they did in reinforcement, but also that this variation has not increased enough to change the overall structure that was seen during reinforcement. This is consistent with the findings of Goldberg (1959), Margulies (1960), and Neuringer et al., (2001). If

variation increases as a result of low rate responding, as in the Neuringer, (1991) study, then increased variation should be seen only during the later extinction sessions, and in the later minutes of an extinction session, when response rate is assumed to be very low. It is hypothesised that across reinforcement sessions, responses outside the effective region should reduce. Also, as previous studies (i.e. Anger & Anger, 1976; Wickens & Miles, 1954) suggest, after experience of some series of extinction, response rate in the initial sessions should appear little different to response rate in later sessions of any single extinction series.

## Method

### *Subjects*

Six Brown Shaver hens, beginning the experiment at 2 years of age, were numbered 501 to 506. Hens were maintained at 80% of their free-feeding body weights or just below laying weight. Hens were housed in cages 500mm wide, 500mm deep and 425mm high. Water was freely available in their home cages. Grit was provided weekly. Wheat was used as a reinforcer during sessions. Between sessions, or where hens did not receive adequate reinforcers, hens were given commercial laying pellets (after sessions) to maintain a constant weight. All hens had prior experience with operant experiments.

### *Apparatus*

The experimental chamber used was made of 2cm thick particle board and painted black on the inside. The internal dimensions were 400mm wide, 500mm high and 560mm long. There was no light source inside the chamber other than the magazine and stimulus light. The floor was covered with a grey mat.

On one wall of the chamber (referred to as the front end), two rectangular holes were cut in the particle board. The first hole was large enough to allow access to the screen and detector. The dimensions of this rectangle were 318mm wide, 230mm high, located 268mm above the floor of the chamber and 41mm in from each side. The second rectangle, located 100mm from the floor of the chamber, and 160mm from the either edge of the rectangle to the sides of the chamber, allowed access to wheat provided by the magazine during a reinforcement. There was 50mm between the top of the bottom rectangle, and the bottom of the top rectangle.

The stimulus was presented on a computer screen. The stimulus was a square of 80 by 80 pixels or 23mm by 23mm, located 505 pixels from the left edge of the screen and 230 pixels from the bottom. This square stimulus was present for the entire session, every session. Sitting directly in front of (and in contact with) the computer screen was an infra-red (IR) detector used to detect the location of each and every response (peck) made when an IR beam was broken. The IR detector was 12inch (327.2mm wide, and 237.2mm high), of the brand IRTOUCH systems, specifically; IRTOUCHSCREEN 12" USB. The IR detector had 1024 IR beams on the x axis (length) and 768 on the y axis (height). Whenever an object broke any beam of the IR detector, the location on the x axis and y axis was recorded. For each response detected, the location (X axis and Y axis values), time and whether or not the response occurred within the stimulus, and the number of reinforcers gained was recorded in a computer system.

When a correct response was detected, and the schedule requirements were met, the magazine operated allowing the hen access to wheat for 3 seconds. When the magazine operated, a 1-W light above the feeder hole was lit.

### *Procedure*

#### *Conditions*

For any reinforcement condition, sessions ceased when either 30 reinforcers were gained, or 40 minutes elapsed, whichever came first. The schedule was fixed-ratio (FR) schedule requiring in which 5 responses on the square stimulus were considered effective and produced reinforcement. During reinforcement sessions the square stimulus remained on. During a reinforcement consisting of a duration of 3 seconds access to grain with a light above the magazine turned on also for the same duration of time, the square stimulus remained present and if any pecks

occurred either on or around the square stimulus during reinforcement these pecks were still recorded. Extinction sessions were identical to reinforcement sessions with one difference; hens received no reinforcers (and also the light above the magazine remained off) during all extinction sessions. After the last hen had finished her session, all hens were given post-feed, in their home cages, in order to maintain body weights.

All hens began the experiment in reinforcement condition one (Rft.1), then experienced extinction condition one (Ext.1), then reinforcement condition two (Rft.2) and so on for a total of six conditions. Hen 501 had one extra session day in Rft.1 due to equipment problems.

To reinstate pecking after an extinction condition, hens each received one session of an FR1 schedule for a total of five reinforcers, with a maximum duration of 40 minutes. One free (no pecks were required) reinforcement was given to any bird which did not peck the stimulus after 15 minutes. This free reinforcement was recorded and counted so that in the remaining session time there were only 4 reinforcers yet to be gained.

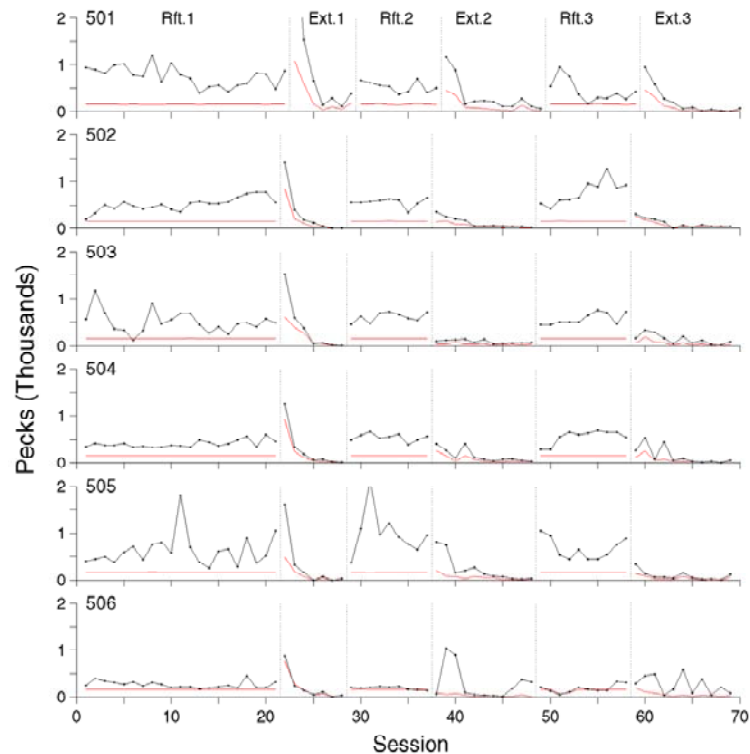
Data from all birds and all sessions were graphed to show total correct and total incorrect responses. When two observers agreed there was no change or visible trend in this graphed data for five out of six birds for the current condition, a condition change was made.

The conditions were the same for all birds, and all birds changed to a new condition on the same day. The number of sessions within each condition did vary. In Rft. 1 there were 21 sessions for each bird (note bird 501 had 22 Rft.1 sessions). Reinforcement conditions 2 and 3 had 9 and 10 sessions respectively, and extinction conditions 1, 2 and 3 had 7, 11 and 10 sessions respectively.



## Results

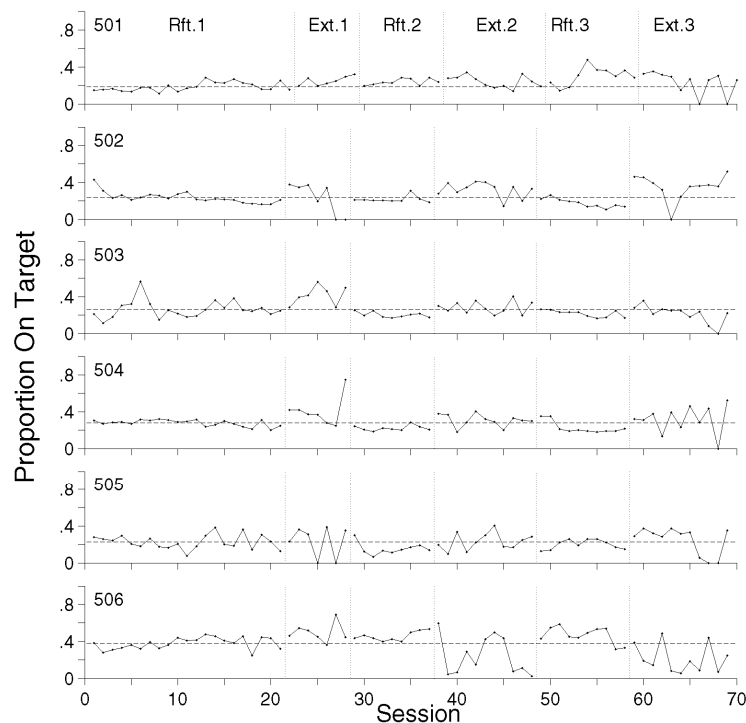
Figure 1 displays the total number of on and off-target pecks for all sessions in each condition. Figure 1 shows that the effect of the first extinction was to greatly increase the total number of pecks. Please note that to provide reasonable graphs, where there are extreme values these are truncated by the axes which are made suitable for the majority of the data (as can be seen in Figure 1, Bird 501, Ext.1). Generally, it is the number of off-target pecks, much more than the on-target pecks, that increased during extinctions. Following extinctions did not result in the same increase in pecks, both on and off-target, except for Bird 506 in Ext.2. After the initial increase in total number of pecks in Ext.1, the number of on and off-target pecks reduce across sessions. A similar, although small, effect can be seen at the onset of other extinction conditions, for some birds. Often, at the onset of Ext.2 or Ext.3, total on and off-target pecks had reduced in number in the first session compared with the last session of the previous reinforcement condition. In Ext.2 and Ext.3, the number of pecks tended to remain low but stable across all but the first two or three sessions in each extinction series. Bird 506 is the exception to this general observation. In Ext.1, two birds ceased pecking; Bird 502 sessions 6 and 7, and Bird 505 sessions 4 and 6. No birds stopped pecking in Ext.2, but two birds stopped pecking in Ext.3 (Bird 502, session 5, and Bird 504, session 10). There was little or no effect of any extinction condition on following reinforcement conditions. Total on and off-target pecks remain stable for each bird throughout all sessions in each reinforcement condition, although for two birds the number of pecks did begin to look different when the first reinforcement condition was compared with the third (Bird 502 and 504). It can also be noted that after Ext.1, Bird 505 had a large increase in the total number of off-target pecks over the first three Rft.2 sessions, but this result is only one exception.



**Figure 1.** Total on-target pecks (unmarked line), and total off-target pecks (marked line). The number within the top left corner of the graph is the bird number. “Rft.” stands for ‘reinforcement’, “Ext.” stands for ‘Extinction’. The numbers after Rft. and Ext. indicate the number of times a condition has been presented. Conditions are separated by dotted vertical lines.

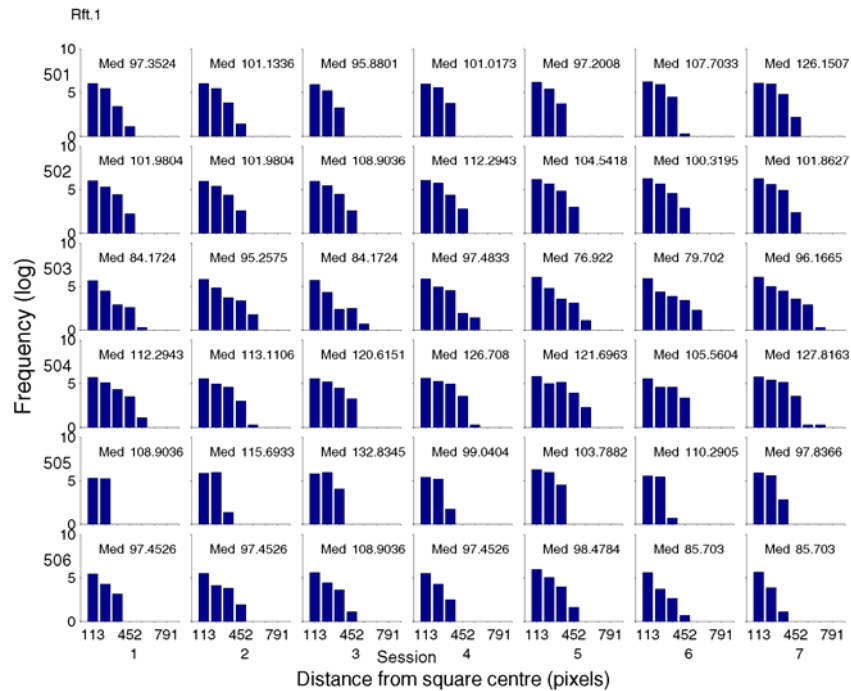
Figure 2 displays the proportion of on-target pecks across all sessions, all birds and all conditions. Apart from a few instances (e.g. Bird 504 Ext.1, session 7), the proportion of on-target pecks was always less than 0.5. Generally in extinction, the proportion of on-target pecks increased when compared to the previous reinforcement sessions. This is easily observed in Ext.1 across all birds, and for most birds in Ext.2, and also for birds 502, 504, and 505 in Ext.3. For most Ext.2, and Ext.3 sessions, the proportion of on-target pecks for Bird 506 was much lower than in previous reinforcement conditions. The proportion of on-target pecks became more varied in Ext.2 and Ext.3 than in Ext.1 (see birds 506 Ext.2, 504 and 506, Ext.3).

Extinctions did have an effect on following reinforcement conditions proportion on-target results for some birds. During reinforcement conditions, were there was a clearly visible change in proportion values after an extinction condition (as there was for three of the six birds), this change was more often a decrease in the proportion of on-target pecks. Rft.2 for birds 503 and 505 shows the proportion of on-target pecks decreased, when compared to Rft.1. Only birds 501 and 506 had increased their performance in Rft.3, observable from the increased proportion of on-target pecks. Proportion on-target pecks gradually decreased across Rft.3 sessions for Bird 502.



**Figure 2.** Proportion of on-target pecks for each bird across all sessions. The dashed horizontal line indicates the average proportion from Rft.1, and continues across all conditions for ease of identifying changes. The number within the top left corner of the graph is the bird number. “Rft” stands for reinforcement “Ext” stands for extinction; numbers following these indicate the number of times a condition has been presented. Conditions are separated by dotted vertical lines.

Figures 3 to 6 display the frequency distributions of pecks in distance blocks from the square stimulus, for each bird and for seven sessions in each condition. The frequency distributions of each reinforcement condition show no significant difference so only results for the first reinforcement condition (Figure 3) are shown here. The graphs of Rft.2 and Rft.3 are on the CD for reference if needed. In Figure 3 it is clearly visible that most pecks occur within or very near the square stimulus and as the distance from the centre of the square stimulus increase the frequency of pecks decreases. Some birds are more accurate than others, for example, if comparing birds 503 and 505, Bird 505 has pecks in no more than three distance blocks, while Bird 503 has pecks in up to six distance blocks. In Extinction one, Figure 4, apart from slightly increased frequencies, the distributions retain the same shape as was seen during reinforcement, for most sessions. In sessions 5 to 7 of Figure 4, some changes in the distributions can be seen, for example in Bird 503 and 506. In Extinction two, Figure 5, the frequencies of pecks remain higher than what was seen across Extinction one. Only for one bird does variability clearly increase over some sessions. Results of Extinction three (Figure 6) are similar to those seen in Extinction two.



**Figure 3.** Frequency distributions of peck locations in distance blocks of 113 pixels beginning from the centre of the square stimulus (which is itself 113 pixels from centre to corner). Due bin distances being circular, some pecks immediately outside of the square stimulus are counted as occurring within the first bin distance block. Seven sessions are displayed for each bird for the condition as indicated on the top left of the figure ("Rft."; reinforcement, "Ext."; extinction, the numbers refer to the number of repetitions of the current condition). Median distance (Med) values are indicated for each session. For reasons of conserving space, this figure legend is not repeated for figures 4 to 6.

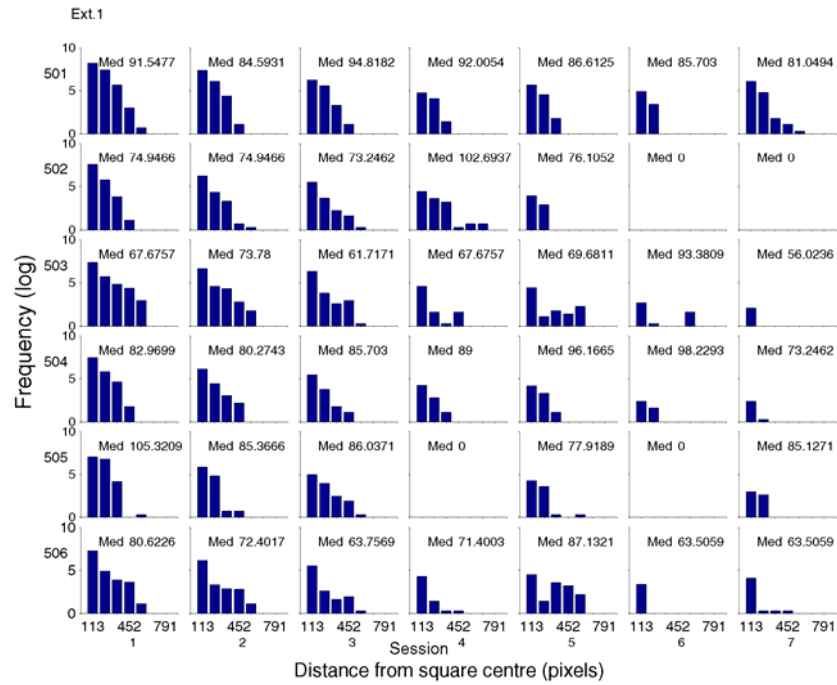


Figure 4. As was written for Figure 3.

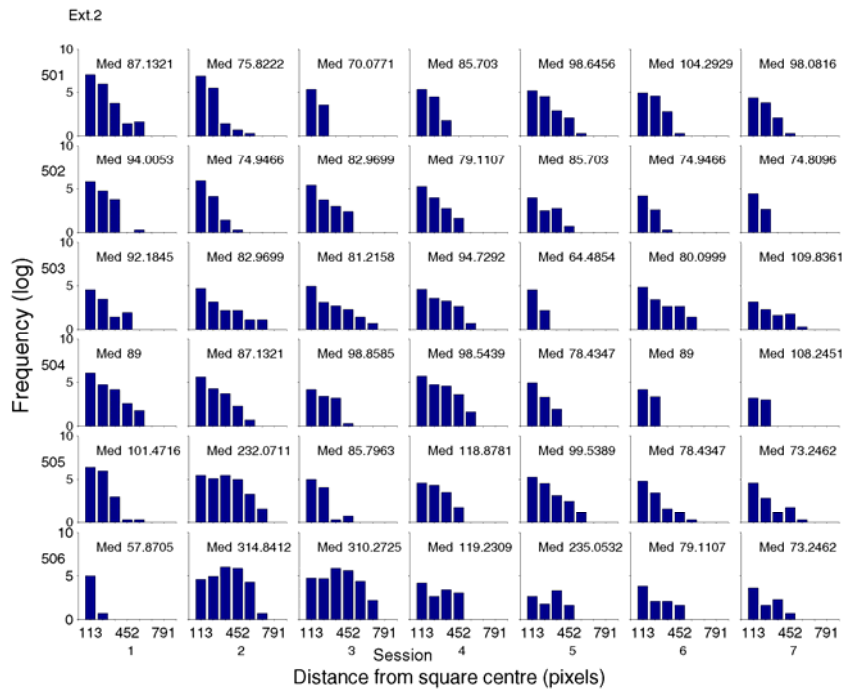


Figure 5. As was written for Figure 3.

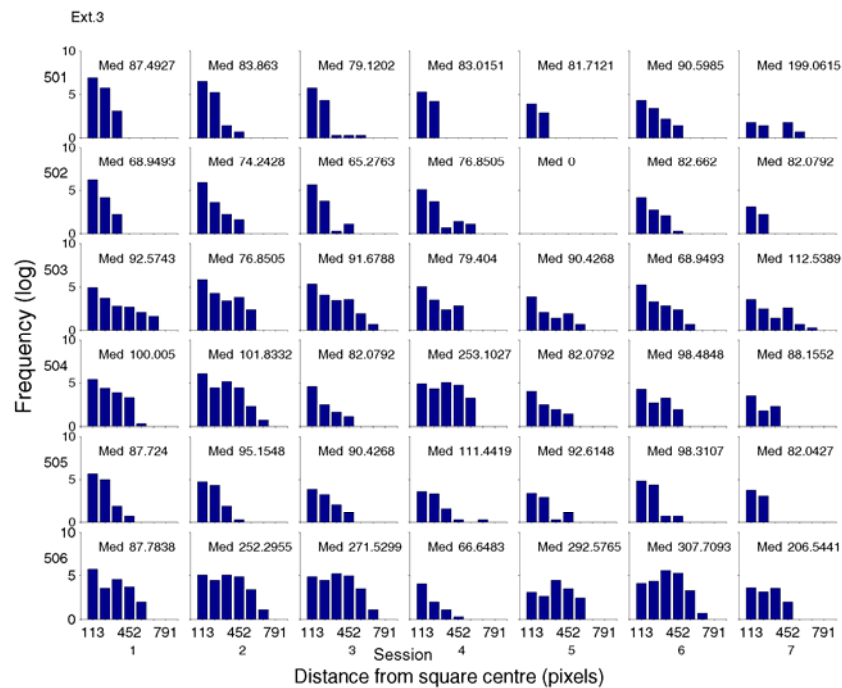
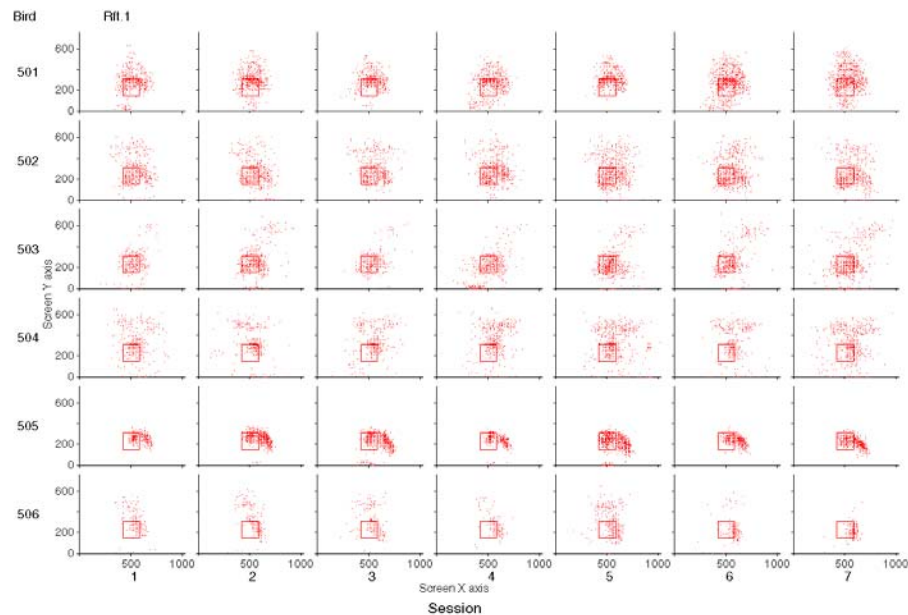


Figure 6. As was written for Figure 3.

Each bird has a pattern of pecking. These patterns can be seen in Figures 7 to 12 (note each figure represents a different condition, as indicated). Looking at Figure 7, the pattern of pecks seen for Bird 505 can be easily distinguished from the patterns of other birds. This same pattern is observable across all sessions in Figure 7, and also across most sessions of Figures 8 to 12. Bird 505 is a good example for how the individual patterns are maintained throughout conditions, as this is also the case for all birds. Bird 501 pecks consistently from the middle of the square stimulus and slightly above. Bird 504 has a pattern where most pecks are condensed around the top right corner of the square stimulus, and also there is a band of pecks that occur above the square stimulus, and Bird 506 pecks mostly on the right side of the square stimulus, and also with a short band of pecks directly above the square stimulus. Figures 7 to 12 also divide the session into two parts; red points represent

pecks made within the first 10 minutes of a session, and black points indicate all pecks made after 10 minutes of a session. Reinforcement sessions were usually completed within 10 minutes, so very few black pecks are seen in these conditions. During Rft.2 (Figure 9) and Rft.3 (Figure 11) birds 504 and 505 tended to have reinforcement sessions longer than 10 minutes, and hence more black pecks in some sessions. In extinction sessions (Figures 8, 10 and 12), typically the first 10 minutes of pecking resembled the individual patterning seen during reinforcement sessions, for each bird. In Ext.1, session 1, as seen in Figure 8, there are so many pecks made after the first 10 minutes that they cover up most peck locations from within the first 10 minutes. The lack of visible red points does indicate that most pecks made after the first 10 minutes were still within the typical patterning of each bird, for this session. Later sessions in Ext.1 (Figure 8) have fewer black pecks, and red pecks are still within the usual patterns of individual birds. In Ext.1 the pattern of pecks from Bird 505 are slightly 'shorter' than what was seen in Rft.1 sessions. In the last few sessions of Ext.1 and for most birds, there are fewer pecks, these pecks being mostly within the first 10 minutes, and also slightly more accurate; as if the typical patterning of pecks has shrunk to be closer to the square stimulus. Bird 506 session 5 is an exception to this, with many black pecks above the square stimulus in this session. Ext.2 (Figure 10) is similar to Ext.1. Red pecks are typically within or close to the square stimulus, and black pecks are away from the square stimulus. In Ext.2, there are in general fewer black pecks than was seen in Ext.1 (especially when comparing the first few sessions of Ext.1 and Ext.2), and more red pecks in later sessions. Also in Ext.2 and in Ext.3, while the majority of pecks are in or around the square stimulus, there are cases where a large increase in the number of pecks after 10 minutes of the session, and outside the square stimulus as well on occasion outside the birds' usual pattern, has occurred. Peck patterns do not 'condense' in Ext.2 and Ext.3 as was seen in Ext.1.





**Figure 7.** Pecks are plotted on axes that correspond to the dimensions of the actual screen. The outlined square (red) represents the edges of the square stimulus. Red points represent pecks that occurred within 10 minutes of the session, black points represent pecks that occurred after 10 minutes. For each bird, seven sessions are presented, the condition indicated by “Ext” or “Rft” for extinction, or reinforcement respectively, the following number indicates the number of repetitions this condition has had. Due to reasons of conserving space, this figure legend is not repeated for figures 8 to 12.

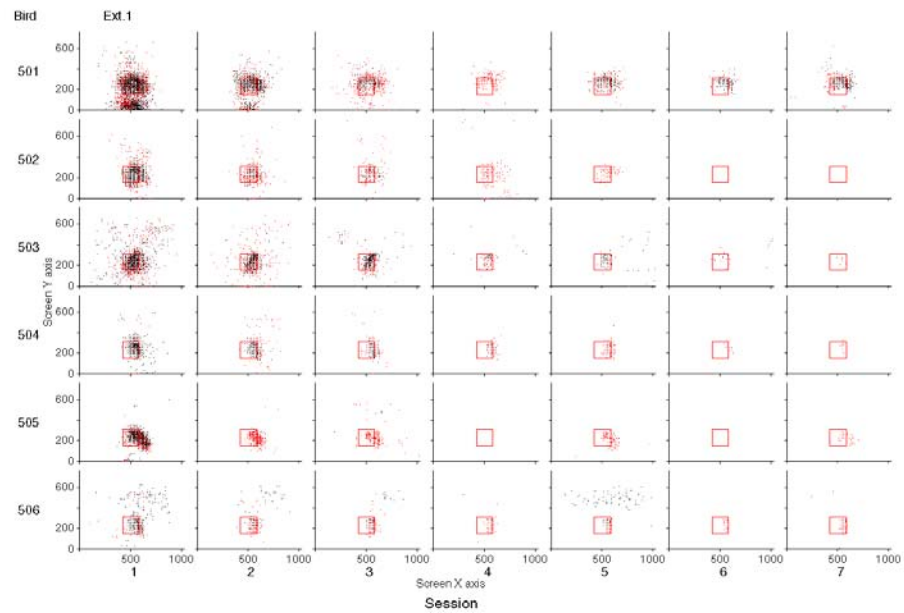


Figure 8. As is written for Figure 7.

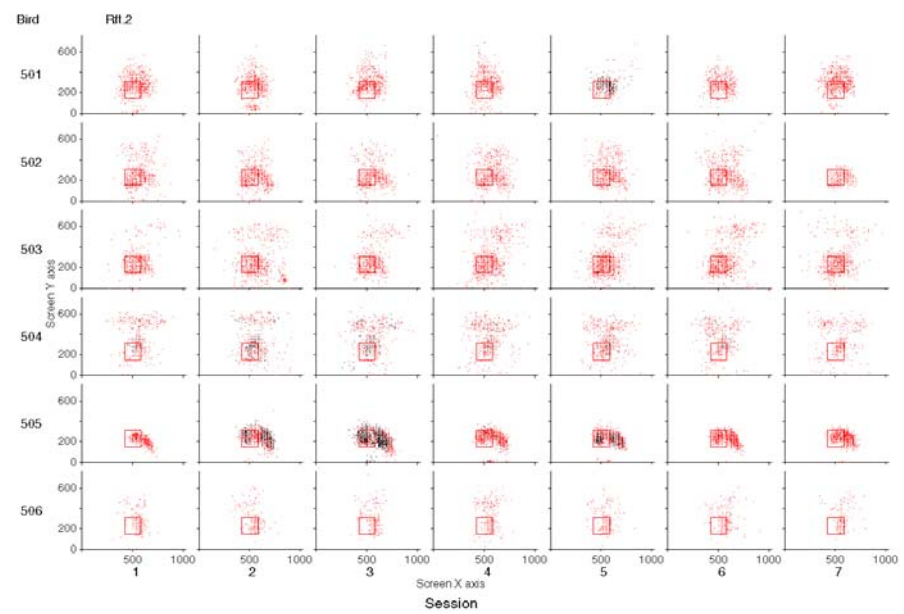


Figure 9. As is written for Figure 7.

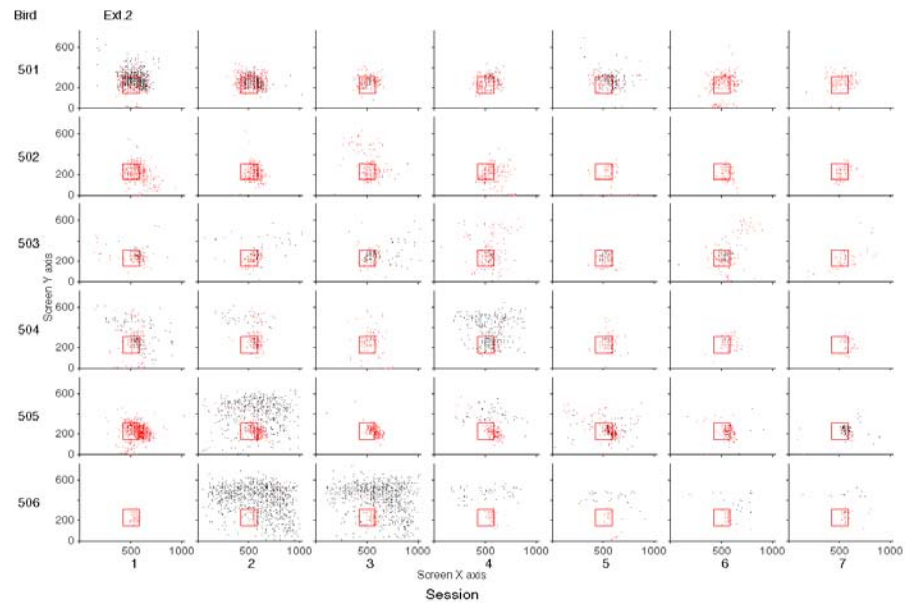


Figure 10. As is written for Figure 7.

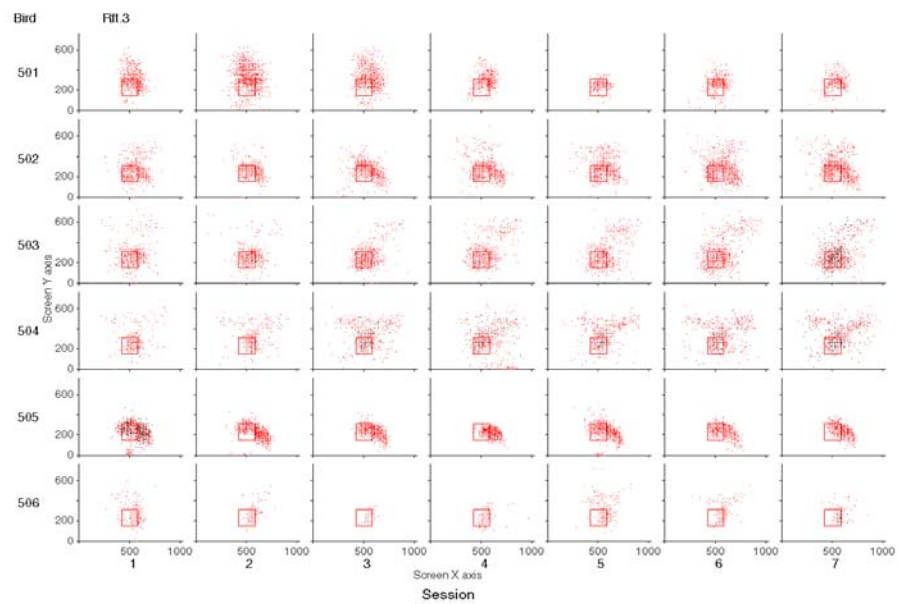


Figure 11. As is written for Figure 7.

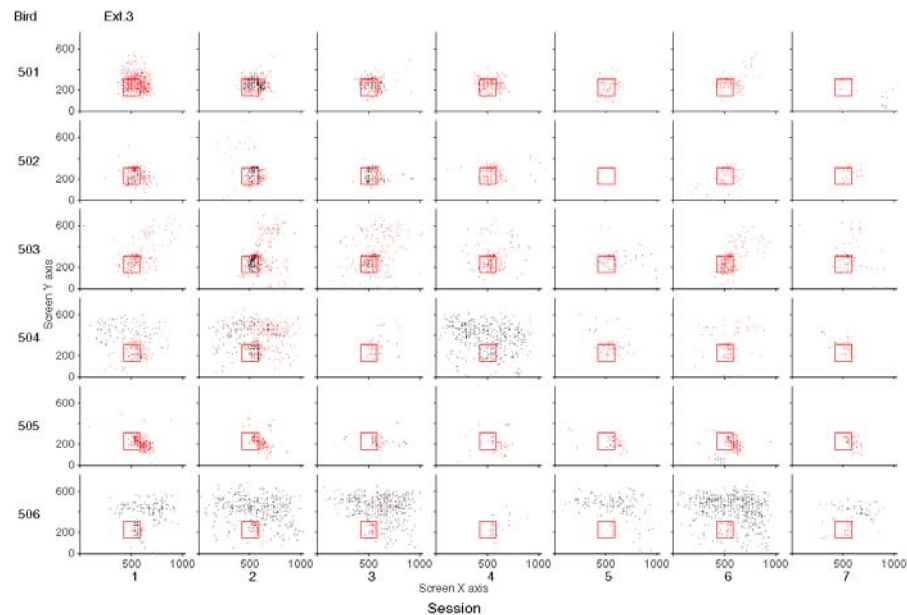
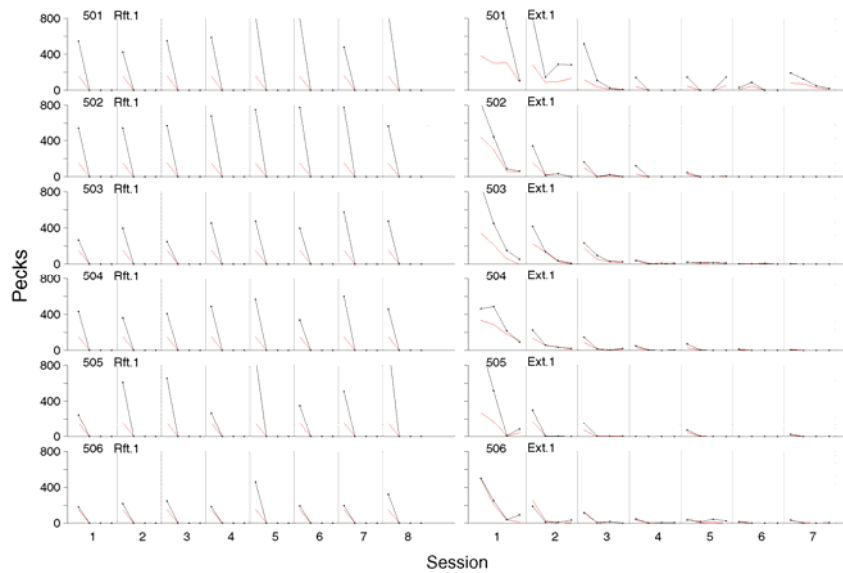


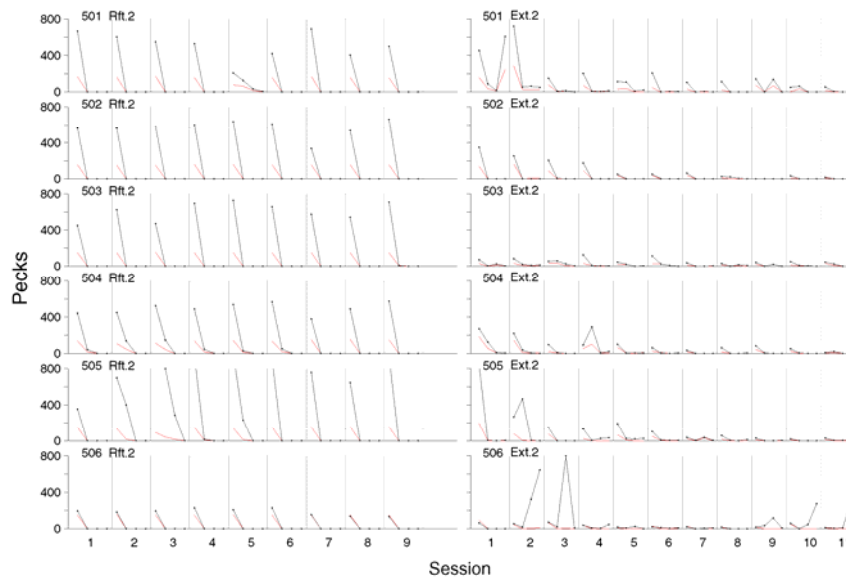
Figure 12. As is written for Figure 7.

Figures 13 to 15 displays the total number of pecks, both on and off-target, for each quarter of a 40 minute session. For Figures 13 to 15, left graphs show sessions of a reinforcement condition, graphs on the right show results for every session of the following extinction condition. Reinforcement sessions are usually less than 10 minutes long, and hence typically only have one quarter with pecks. Due to the schedule requirements the total number of on-target pecks almost always equals 150 pecks for all reinforcement sessions. Considering all conditions, as displayed in Figures 13 to 15, the following discussion applies to each figure. The total number of off-target pecks varies across sessions within birds, and across birds, for all reinforcement sessions. There are only a few instances, throughout all sessions and across all conditions, where the total number of on-target pecks is at a value higher than the total number of off-target pecks. More variation in pecking is seen typically only with the off-target pecks, across all sessions and all conditions. The total-

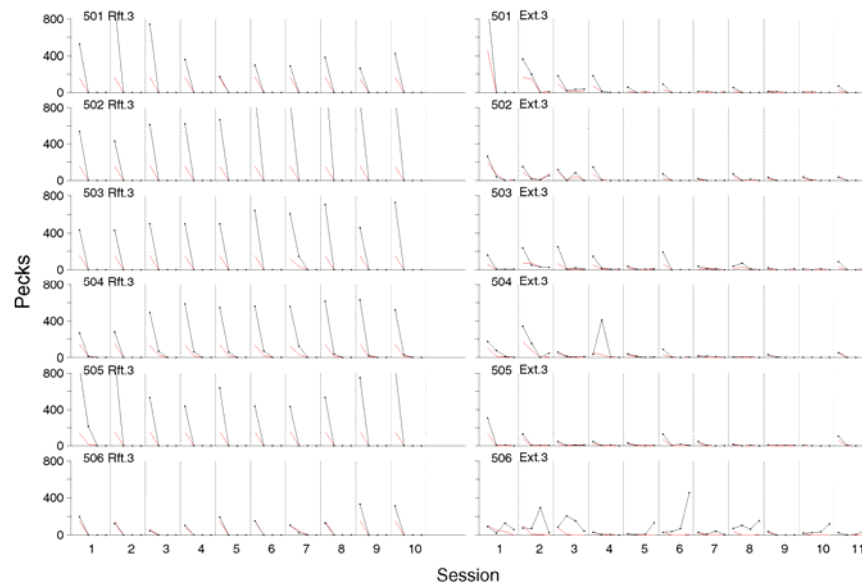
number of on-target pecks can vary somewhat during the first few sessions of an extinction condition. Looking at Figure 13; in Ext.1, session 1, the first quarter shows that both on and off-target pecks have increased in number to values above those seen in the previous reinforcement condition, Rft.1, for all birds except Bird 504. Following extinction sessions then show a gradual decline in the total number of off-target pecks across the first quarter of each session, with the same declining trend seen across the quarters within a session. This declining trend across session quarters (within a session) in extinction becomes less apparent in later sessions of Ext.2 and Ext.3, because for most birds, the total number of pecks is almost zero after only the first session quarter. There are some exceptions, Bird 506 for example, where the total number of off-target pecks increases in later parts of the session. The decline in off-target pecks is usually at a faster rate than the decline in on-target pecks across extinction session quarters, although as a general trend, this only applies to comparisons made between the first and second session quarters. Where there are very few pecks in later sessions, pecks are more frequently made within the first 10 minutes only (with some exceptions e.g. Bird 506). The initial increase in pecks across the first quarter is not seen as strongly in Ext.2 or Ext.3, as was seen in Ext.1, session 1, for all birds. In Ext.2 more frequently across sessions, pecks were made in the later parts of the session (compared to the first quarter) than was seen in Ext.1. There is no increase in pecks for the first quarter of the first Ext.3 session, except for Bird 501 which then quickly stops pecking. For Bird 502 there can be seen a clear increase in the total number of on-target pecks and a decrease in the total number of off-target pecks for the first quarter of the first session. These on and off-target pecks then decline across the quarters, remaining close together.



**Figure 13.** Total on-target pecks for each quarter are represented in red, total off-target pecks are represented in black. Sessions are divided into quarters, each quarter represents 10 minutes (maximum session length is 40 minutes). “Rft” stands for reinforcement, “Ext.” stands for extinction. Number of times a condition is presented is indicated by the number following either “Rft.” or “Ext.” Due to reasons of conserving space, this figure legend is not repeated for figures 14 to 15.



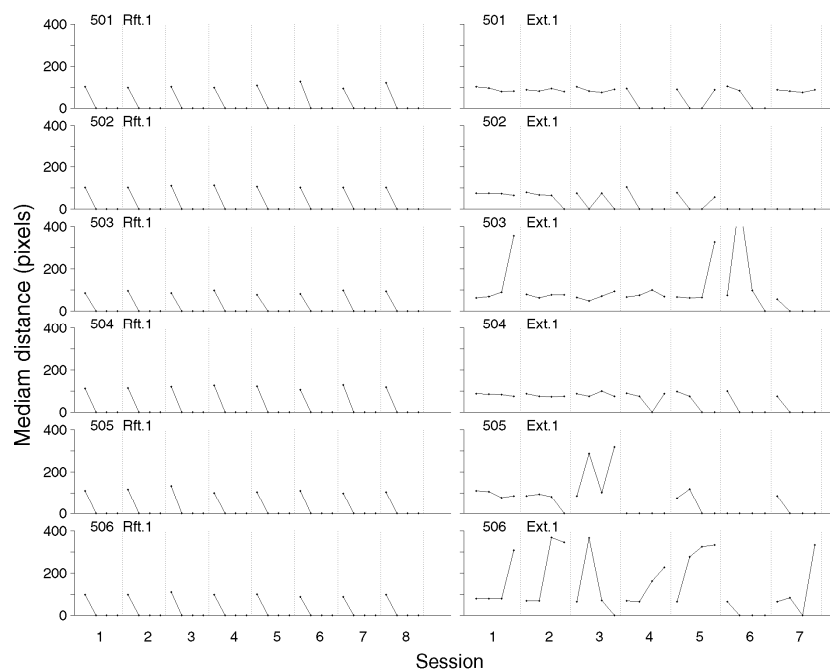
**Figure 14.** As was written for Figure 13.



**Figure 15.** As was written for Figure 13.

Across reinforcement sessions of Rft.1 in Figure 16 the median distance from the square centre is approximately the same for all birds, across all sessions. In comparison, Ext.1 also in Figure 16 shows more variations in median distance in only the later parts of the session for some birds. In other words, the median distance values for the first quarter of all extinction sessions are approximately equal to that seen in reinforcement sessions. Where there are variations, these variations tend to be large increases in median distance away from the stimulus square centre (i.e. see Bird 503, sessions 1, 5 and 6, and Bird 505, session 3, and Bird 506, most sessions). For birds 501, 502 and 504 there is little or no change in median distance across the session quarters for all Ext.1 sessions. Median distance is more varied across all but the first quarter of a session for most sessions, and for more birds in Ext.2 of Figure 17. As with Ext.1, in Ext.2 the median value for the first session quarter, with only a few exceptions, is equal to values seen during reinforcement sessions. Often the median distance increases across session quarters, although there are a few instances where the median distance decreased,

for example, Bird 503 in session 4 and 6, and Bird 504 in session 5. Ext.3 in Figure 18 produced results very similar to those seen in Ext.2. Apart from a few instances where the median distance has slightly decreased in Rft.3 sessions, compared with other reinforcement sessions (e.g. Bird 501 session 5, and Bird 504 session 1), Rft.3 looks much like Rft.1 and Rft.2. In Ext.3 median distance again varies over the last three quarters while remaining at values equal to those seen in reinforcement sessions for the first quarter (with only few exceptions), across all sessions and all birds. There are again a few instances where the median value has decreased within a session, but generally the median distance increases greatly over the last three quarters.



**Figure 16.** Median distance from the stimulus square centre. Sessions are divided into quarters, each quarter represents 10 minutes (maximum session length is 40 minutes). “Rft” stands for reinforcement, “Ext.” stands for extinction. Number of times a condition is presented is indicated by the number following either “Rft.” or “Ext.”. The axes scale was chosen to represent well the majority of the data, and hence occasionally data has been truncated. Due to reasons for conserving space, this figure legend will not be repeated for figures 17 and 18.



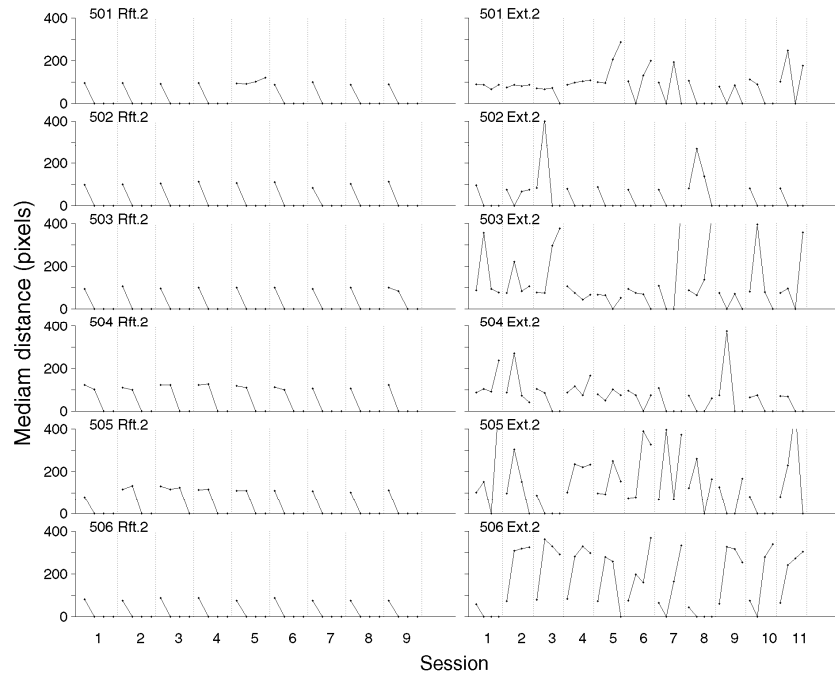


Figure 17. As was written for Figure 16.

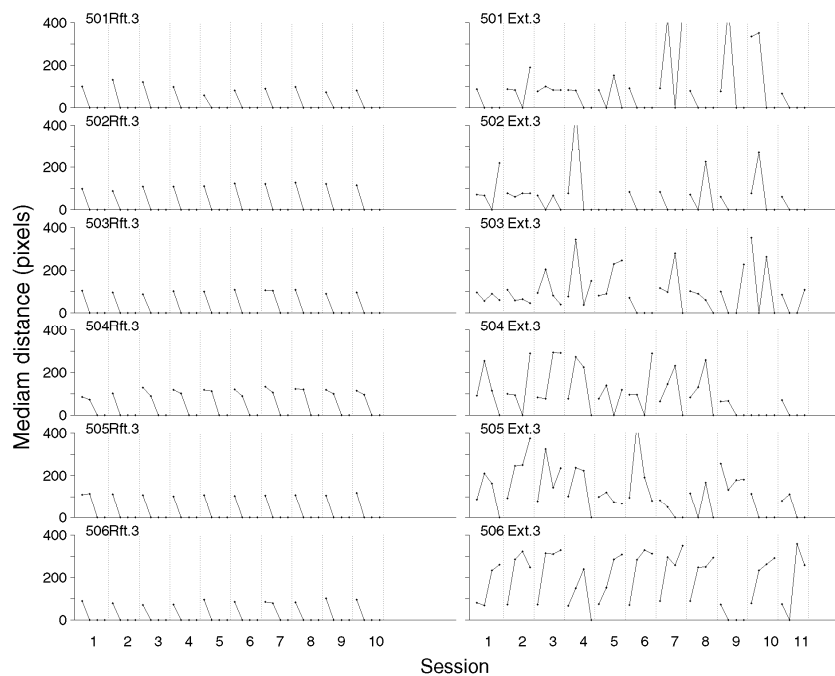
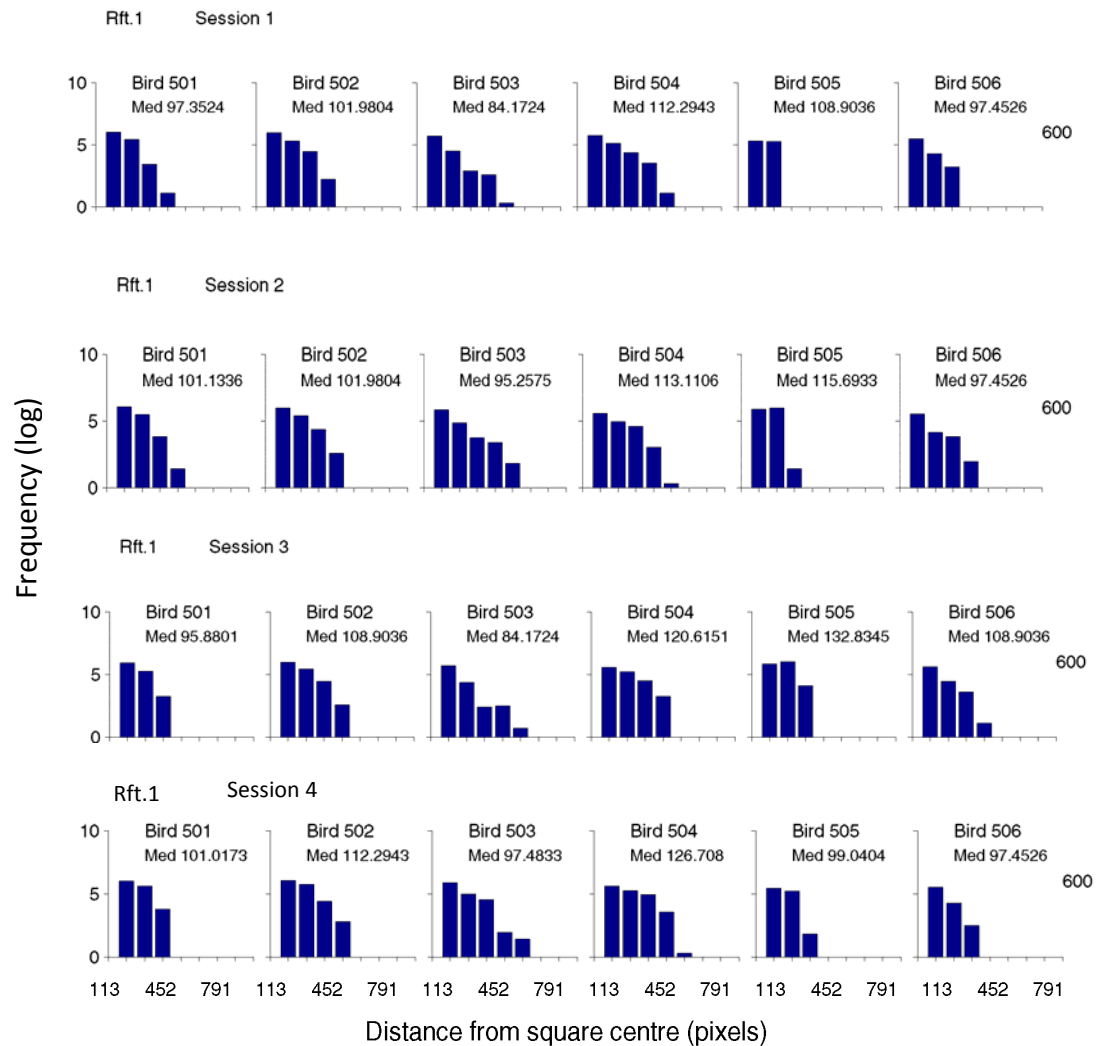


Figure 18. As was written for Figure 16.

Figures 19 to 24 show the frequency distribution of pecks. Pecks were recorded into distance 'bins'. Measuring from the top left corner to the centre of the square stimulus, the distance was 113 pixels. Each distance bin was equivalent of this distance; 113 pixels wide, with the first bin being measured from the centre of the square stimulus, the second bin had a radius of  $113+113$  pixels, minus the previous 113 pixels, and so on. The number of pecks recorded for each session quarter and in each distance bin were recorded and graphed to give an indication of where the pecks were located in relation to the centre of the square stimulus. (These are a sample of many graphs; other graphs can be viewed in the CD). From the sample of Rft.1 sessions in Figure 19, it can be seen across sessions, within each bird, there is little change in the frequency distribution of pecks in each distance bin. Although between birds there are differences in the distributions of pecks. Bird 505 has most pecks within the first two distance bins, and only a few pecks in the next distance block. Bird 506 also has a narrower distribution of pecks than other birds, although this is not as narrow as the distribution of Bird 505. Reinforcement sessions were quite alike, some sessions having pecks in more than just the first session quarter, but otherwise there was little difference between conditions so these graphs were not presented here.

Ext.1 shown in Figure 20 displays across all four session quarters the frequency distributions of pecks for each bird. Session 1 of Ext.1 shows similar pecking in the first quarter as was seen during Rft.1 sessions, although the bars are slightly higher. Changes appear in the third quarter of session 1, where total number of pecks decline, and this decline is seen more in bins further from the square stimulus. By the fourth quarter the distribution of pecks has again changed, so that for some birds, more pecks occur away from the first bin (square stimulus). For example, compare session quarters 3 and 4 of Bird 503, and also Bird 506. By session four of Ext.1 (Figure 21) only three birds are pecking in more than the first session quarter. Birds 503 and 504 becomes more accurate in the last quarter. The first quarter of

session four (figure 21) are slightly more accurate than the first quarter for Rft.1 sessions, except for Bird 502. In Ext.2, session one, Figure 22, the first quarter is slightly more accurate than reinforcement first quarters. Following session quarters have fewer pecks overall (birds 502 and 506 have no pecks after the first quarter). For two birds (504 and 505) the median values increase greatly in the last session quarter. In session four of Ext.2 (Figure (23) all but Bird 502 continue to respond in all four session quarters. For birds 505 and 506 more pecks are further from the square centre, and for Bird 503 most pecks are very near the square centre. For all birds except Bird 503, the median distance value as presented on individual graphs, have increased in the last quarter compared to the first quarter. The first session of Ext.3 (Figure 24) shows most pecks occurring within the first session quarter, and birds 504 and 506 with more pecks further away from the square centre, as indicated by the increasing median values across quarters. In contrast, Bird 503 tends to become more accurate across the quarters, also with fewer pecks.



**Figure 19.** Frequency distributions of peck location. Condition series and session number as indicated at top of graph. ‘Bins’ are same width; 113 pixels (radius measured from the square centre to an edge of the square). The first bin contains all pecks within and immediately around the square (due to a bin distance being circular). The session is divided into quarters, each quarter representing ten minutes of a 40 minute extinction session (as indicated by the values to the right of the graph), for each bird, all conditions except for Rft.1. The median value for each session part is also given (“Med” and value). Due to reasons for conserving space this figure legend is not repeated for figures 20 to 24.

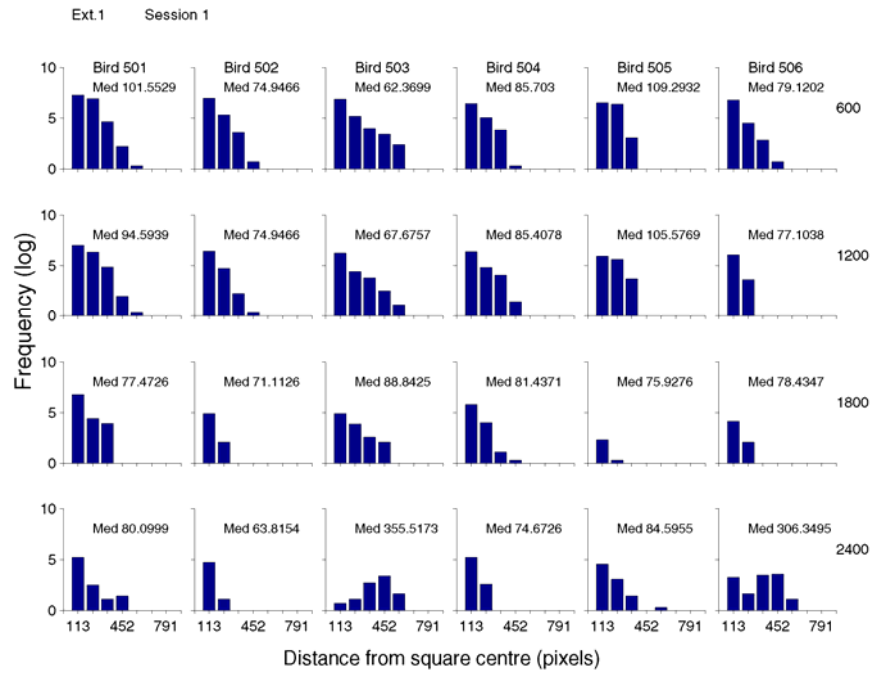


Figure 20. As was written for Figure 19. Ext.1, session 1.

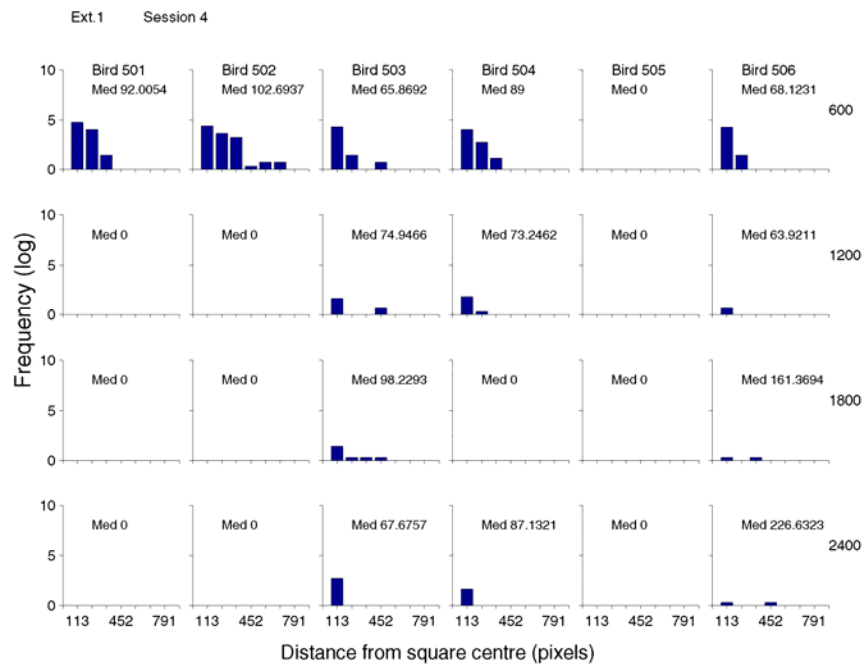


Figure 21. As was written for Figure 19. Ext.1, session 4.

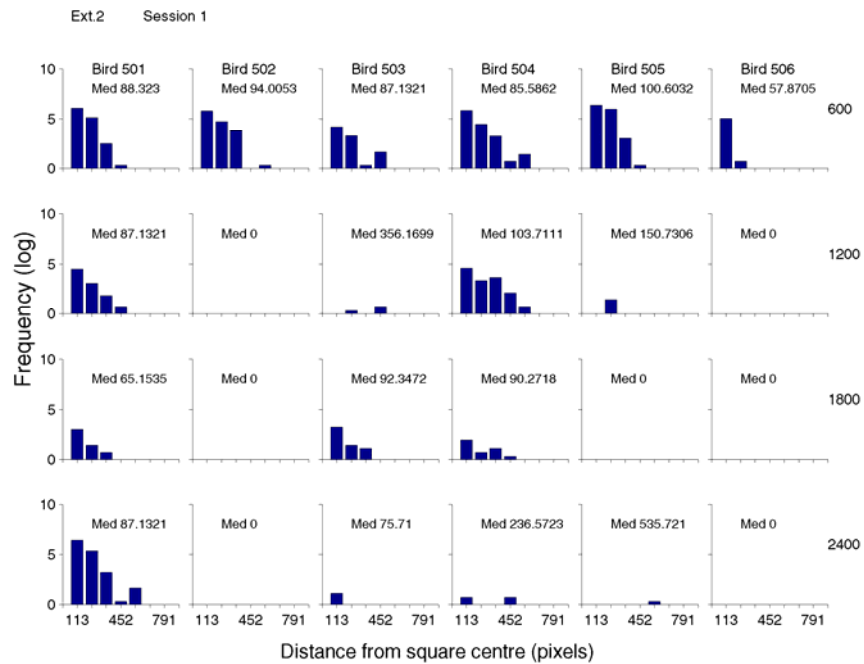


Figure 22. As was written for Figure 19. Ext.1, session 1.

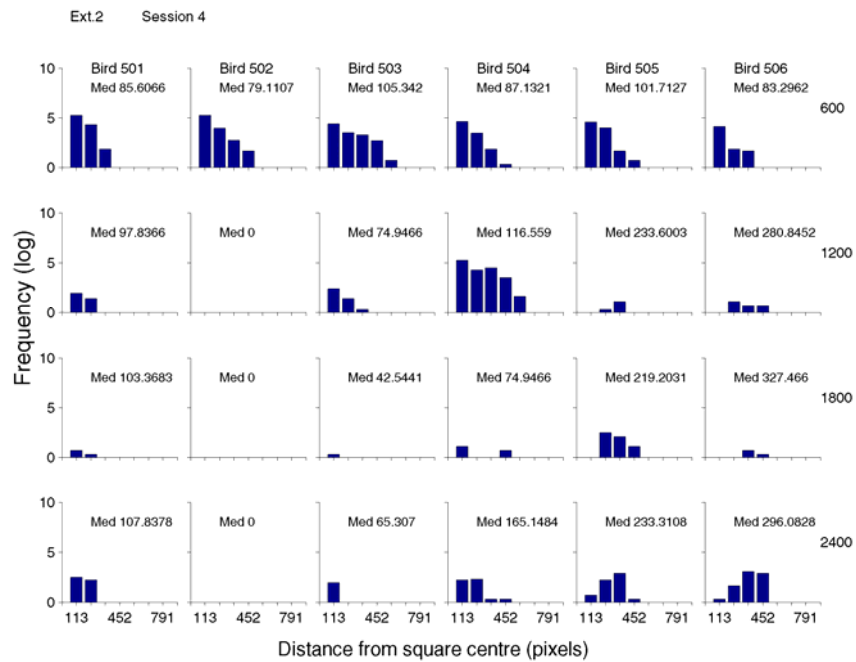


Figure 23. As was written for Figure 19. Ext.1, session 4.

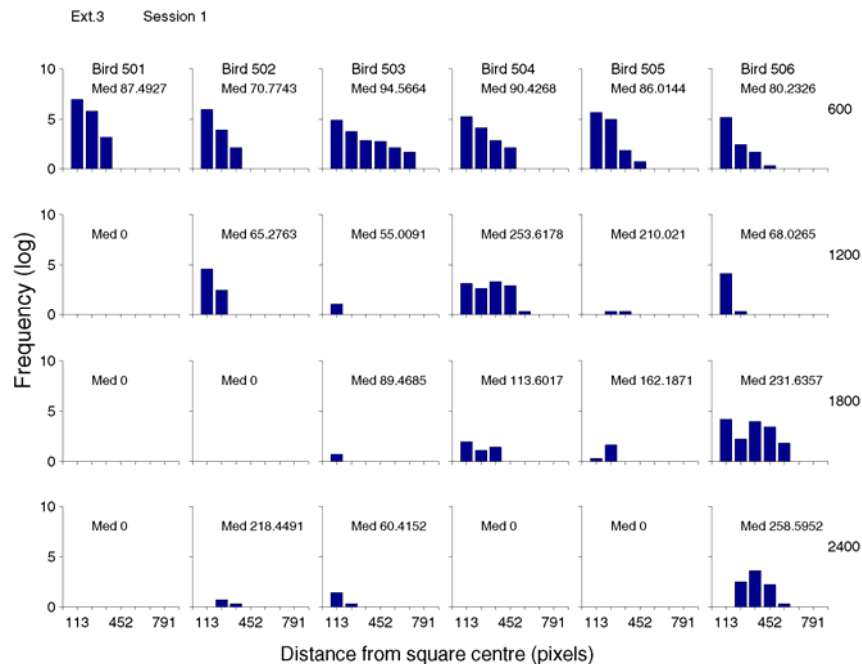
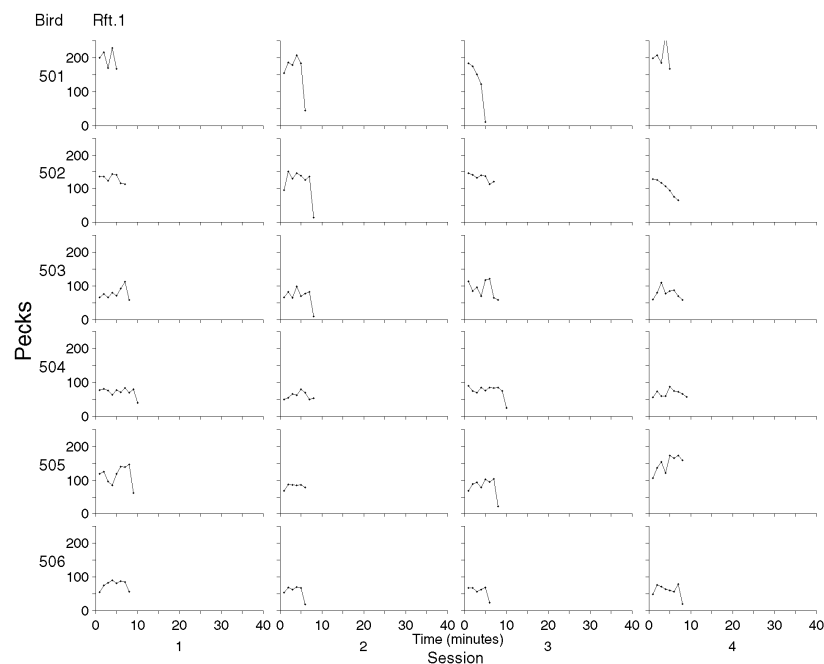


Figure 24. As was written for Figure 19. Ext.1, session 1.

Figures 25 to 28 show the peck rate per minute, for each bird, in each condition. Figures 26, 27 and 28 represent the first four sessions of each extinction condition. Figure 25 displays the last four sessions of reinforcement one, which is also representative of peck rate across reinforcement conditions two and three. The graphs of Rft.2 and Rft.3 are on the CD for reference if needed. Birds are consistent with the number of pecks made per minute across most reinforcement sessions for all conditions, yet during extinction sessions, pecks per minute can vary greatly across the session. There was no observable 'burst', or increase in peck rate at the onset of extinction, for extinction sessions one or any other session. At the onset of extinction peck rates began at rates seen during reinforcement sessions, and in the case of session one, Ext.1 (see Figure 26), persisted for 10 to 15 minutes before declining across the remainder of the session. For all other sessions in extinction, birds did not persist longer than a few minutes at rates equal to those seen during reinforcement. Pecking in extinction conditions two and three (Figures 27 and 28

respectively) was quite different to that seen in extinction one. In these sessions, pecking tended to occur more as ‘peaks’, i.e. as short bursts of pecking preceded and followed by periods on non-pecking. For Bird 506 in Ext.2 of Figure 27, these peaks occurred nearer the end of the session, and not at the beginning of the session. In Ext.3, Figure 28, these peaks of pecking are more obvious, and more frequent than in Ext.2. They also occur more frequently near the middle or end of an extinction session, as well as at the start.



**Figure 25.** Peck rate per minute. The total number of pecks that occurred within each minute of a session is recorded for each bird, for the last four Rft.1 sessions, and the first four sessions of all other conditions. The condition (either reinforcement or extinction) the graph represents is indicated by the text at left hand top of the figure, for example, ‘Rft.1’. Due to reasons of conserving space, this figure legend will not be repeated for Figures 26 to 28.



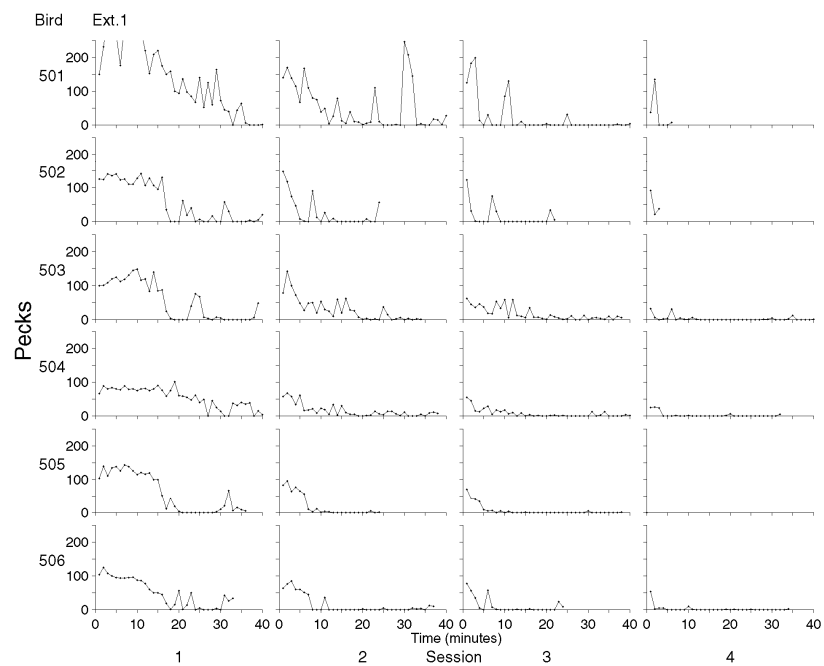


Figure 26. Peck rate per minute. Read as was stated for Figure 25.

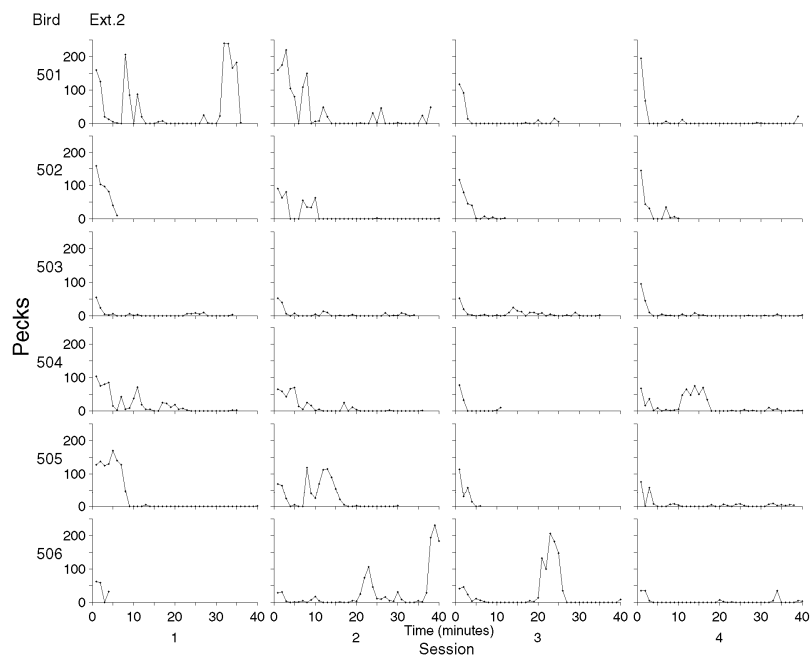
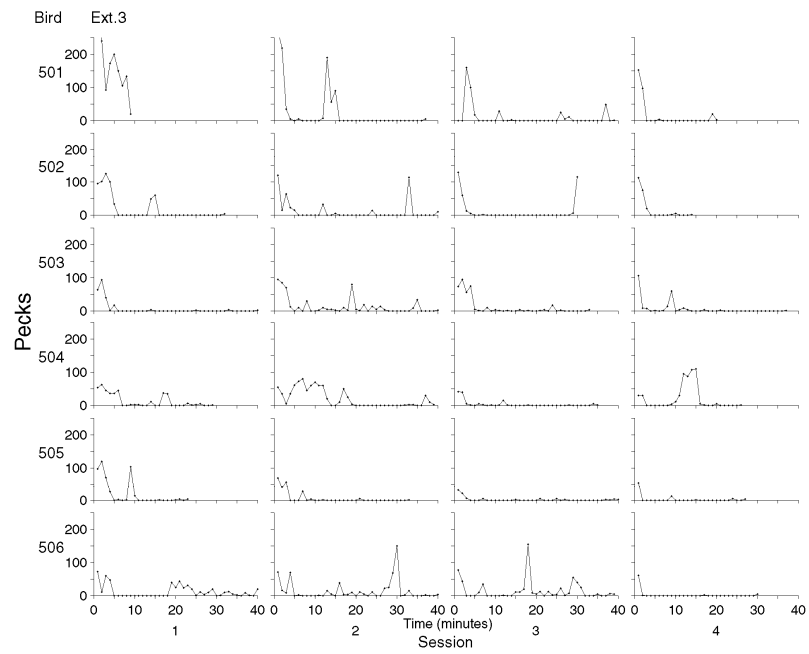


Figure 27. Peck rate per minute. Read as was stated for Figure 25.



**Figure 28.** Peck rate per minute. Read as was stated for Figure 25.

## Discussion

In the current study there was virtually no difference in the response patterns (as seen in scatter graphs) or frequency distributions of peck locations between reinforcement and extinction conditions when observing the distributions for entire sessions. The studies of Antonitis (1951) and Eckerman & Lanson (1969) found response frequency distributions of reinforcement sessions compared to extinction sessions to be very different, suggesting increased variation in extinction, a direct contradiction to the results of the current study. There were differences however between these two studies and the current study which may have contributed to the differing results.

The above studies used a response strip as a measure of variation in location, while the current study used a square stimulus, a much smaller response area in comparison. Perhaps, if in the current study a rectangle stimulus of approximately the same dimensions of the response strip in the Eckerman & Lanson (1969) study was used, then more variation in responding may have been observed in extinction. A rectangle response strip or stimulus provides a larger area of reinforced responses, and also may explain the decrease in variation observed across reinforcement sessions as subjects make more efficient responses, or in other words, respond to the area of the response strip that is closest to the feeder; thus reducing time and energy between responses. In extinction, perhaps the larger area of a response strip facilitates an increase in variation. Responses along the entire response strip may have at some point been reinforced, and also, the entire response strip is relevant for responding because any end of the stimulus is just as relevant as the centre of the stimulus; i.e. the entire stimulus acts as a stimulus, eliciting responses. When returning to the feeding location reduces in frequency during extinction (as was the case with the Antonitis (1951) and Herrnstein (1961) studies), perhaps an increase in variation reflects a reduction in efficient responding as responding close to the feeding location is no longer reinforced, and therefore behaviour becomes less stereotypical. A response strip therefore should encourage

more variation in extinction than what a relatively small square stimulus would otherwise elicit.

The square stimulus of the current study perhaps encouraged responding to 'condense' around the stimulus during conditioning, and discouraged variation in extinction due to responses outside this effective stimulus region having never been reinforced. In other words, perhaps the findings of the current study were a result of having less stimulus area in which variation might have otherwise been elicited.

The results of the current study, however, support the idea that structures remain in extinction; in agreement with the studies of Neuringer, et al. (2001), Nevin (1967), Goldberg (1959), and Margulies (1961), despite the number of differences between these studies and the current study (including different subjects used, and different response measures made). Therefore more study needs to be done on the effects of stimulus area on the variation of behaviour in extinction, as this appears to be the most salient difference between those studies in support of, and those in disagreement with, the idea that structures remain in extinction.

Another important point this study makes is that while, when referring to overall session results structures or patterns do remain intact in extinction, this is not completely true for within session results. In the following paragraphs, results within the typical reinforcement period will be discussed, and then responses outside this period will be discussed.

For the first quarter of most extinction sessions, the rate of responding is similar to the rate seen in any previous reinforcement session, the pattern of responding, the median distance value, and the frequency distributions for the first quarter of each extinction session are also almost identical to any previous reinforcement session. Therefore, the many graphical analyses from the current study strongly support the idea that variability does not increase in extinction, at least for the first 10 minutes of an extinction session. This suggests that behaviour within the first 10 minutes of extinction, or the typical duration of a reinforcement session, does not change,

despite the many successive repetitions of a session beginning in extinction. There is one exception to this rule however; the total number of responses across the first quarter of extinction sessions do change, i.e., responses reduce in number, although, in later extinction sessions responding typically remains at low but stable values. So when does 'extinction', in the behavioural sense, begin?

In the current study extinction sessions were consistently longer than reinforcement sessions, giving very interesting results. An attempt was made to compare these results with results from previous studies but this was difficult as the duration of reinforcement sessions in previous studies was not always stated. For example, in the Antonitis (1951) study reinforcement sessions consisted of (and ceased at) 50 reinforced response chains and extinction sessions were one hour. The duration of reinforcement sessions was not mentioned. In the Eckerman & Lanson (1969) study their reinforcement and extinction sessions were approximately equivalent in length; reinforcement sessions ended after 100 reinforcements, and extinction sessions ended after 100 reinforcements would normally have been gained, i.e. everything was the same, only the feeder was disconnected. A total session length was not mentioned in their experiment, i.e. for when to stop a session if the bird did not make 100 responses. There is one shortcoming to this method of only disconnecting the feeder; if birds pause more or respond slower in extinction, then extinction sessions can be longer than reinforcement sessions, and as results of the current study suggest, this can affect the variation in responding. In the study by Neuringer et al., (2001), both reinforcement and extinction sessions were 30 minutes long, and considering the results of the current study, it would have been interesting to observe variation in behaviour after the 30 minute period, to see if responding became even more variable. To sum up; the importance of when variation occurs, such as within or after the usual period of reinforcement, has rarely been considered, and therefore further study is needed in order to validate the results of the current study.

To expand on the idea that possibly in extinction variation does increase but only after the period that reinforcement was typically available, a different type of experiment is required. For example, if in a study reinforcement was provided for five minute segments, and each reinforcement segment was separated by a 5 minute extinction intervals (resulting in five minutes where responses are immediately followed by reinforcement, then five minutes where responses are not followed by reinforcement, and this pattern repeating several times), and then an extinction condition was introduced in which no responses throughout each session were followed by reinforcement, how would this change responding? If responding during reinforcement sessions occurred mostly within the first, third (and so on) five minute intervals then during an extinction session, would responding be equivalently dispersed into five minute intervals? Also, how would this affect variation of responses on the dimension of interest, for example, location? Would variation increase (in comparison to five minute reinforcement segments) only within the five minute segments of extinction during reinforcement sessions and during extinction sessions, or would variation only increase after the duration of a typical reinforcement session?

One possibility for the increase in behavioural variation on the dimension of location that occurred only after the first quarter of a session, in the current study, is that perhaps stimulus control on behaviour was weaker during last 30 minutes of an extinction session. During reinforcement sessions, the square stimulus was rarely present for longer than 10 minutes, yet in extinction conditions, the square stimulus was present for an entire 40 minute session. This idea was expanded from the theory that the decline in response rate could be due to hens habituating to the stimulus in extinction, a theory proposed by McSweeney, Murphy, & Kowal, (2004). This theory may account for the decline in responses seen across extinction sessions, but does not explain the presence of peaks of responses that occurred within extinction sessions of the current study.

Results from within extinction sessions have proven informative, as has the study of off-target pecks. From the above discussion it is clear that for the first quarter of an extinction session, variability does not increase or decrease. After this period though, there is some evidence for increased variability. The scatter graphs (Figures 7 to 12) show that pecks made within the first 10 minutes are consistently within the birds' typical pattern or pecking. During reinforcement conditions, a much larger number of off-target pecks occurred than was initially anticipated. These off-target pecks did not decline across reinforcement sessions as was expected because these pecks were not being reinforced. For some birds, a 'band' of many off-target pecks can be observed to occur above the square stimulus and almost consistently throughout reinforcement sessions. This 'band' appears to have no function; none of these pecks are reinforced and the potential for these pecks to be 'accidentally' reinforced by occurring in quick succession with a peck on the square stimulus is unlikely. There must be some other explanation for the consistent presence of these 'bands' of off-target responses, but this is unknown.

After 10 minutes of an extinction session, pecks tend to occur more frequently outside the square stimulus, and in some sessions, a large number of off-target pecks occur. The scatter graphs of extinction conditions 2 and 3 (Figures 10 and 12) clearly show this occasional large increase in number of pecks and variation that was observed for birds 504, 505, and 506. These sessions where the number of off-target pecks greatly increased resulted in a distinctly different pattern to the usual pattern of pecks observed for that bird. Sessions with these distinctly different patterns are only seen during extinction conditions, and not during reinforcement conditions. Previously, off-target pecks have not been recorded and this is a very interesting result. In relation to the theory of responses existing along a continuum provided by Catania (1973), and from observing the frequency distribution graphs, it does appear that the majority of pecks occur on or immediately around the square stimulus, and with increasing distance from the square stimulus, fewer pecks occur. In other words, the idea of responses existing along a continuum, and in a bell shape, is supported in the current study. The theory of responses existing

along a continuum, though, does not explain the large number of pecks that occurred outside the birds' typical pattern in some extinction sessions. Considering the many off-target responses that were recorded in the current study, there appears good incentive for future study of off-target responses.

Returning to the findings of within session analysis, measures of peck variation made within extinction sessions have proven very important in gaining further understanding of how behaviour varies in extinction. The results of the current study give evidence in support of the argument that in extinction, while some variation is seen; overall structures (or patterns) remain. After 10 minutes into an extinction session, variation in location increases. The median distance (of pecks as measured from the stimulus square centre) across sessions, as an example, remained relatively constant throughout conditions, yet when observing median distance within sessions (Figures 16 to 18), there was evidence of much variation after the first 10 minutes of an extinction session. The median distance of pecks across entire sessions in each condition can be found on the CD. The frequency distributions of peck locations as observed within sessions (Figures 20 to 24) also showed increased variation in the last session quarter (or the last 10 minutes) of extinction sessions, yet no or very little variation was observed in the frequency distribution graphs of peck locations for entire sessions (Figures 3 to 6), in any condition. These results indicate the increased variability in peck location that may be seen within a session is (usually) not large enough to change the overall pattern or structure of responding. The within session analysis provides information very useful and quite different to that from across sessions.

It was noted in the introduction of this thesis that often an 'extinction burst' is observed at the onset of extinction, before responding begins to gradually decline. The findings of the current study found little or no evidence of an 'extinction burst', which is similar to results of Bullock & Smith (1953), and Tonneau, et al., (2000), the only other known studies with similar findings. From Figure 1 of the current study the number of off-target pecks produced in the initial extinction session of Ext.1 has



a high value in comparison with previous reinforcement sessions, but this was due to the increased session length rather than an increase in the rate of responding. Referring to Figures 26, 27 and 28, the rate of responding seen during reinforcement persisted the longest in session one of Ext.1. At the onset of Ext.2 and Ext.3, behaviour did not persist nearly as much, and responding also tended to occur in response 'peaks' during Ext.2 and Ext.3 conditions. In Ext.3 especially, these 'peaks' of responses tended to occur at the very beginning of a session, followed by a period of non-responding, then another 'peak'.

What happens within extinction sessions, and across individual subjects, has been relatively unstudied, as was mentioned in the introduction of this thesis. One exception to this was the Tonneau, et al., (2000) study, in which response rates per minute were recorded across an entire session for each subject. Within their study, responses were seen to gradually decline in extinction, with some 'peaks' or 'waves' of temporarily increased responding. A similar effect was seen in the current study, but a little more extreme than the results from the Tonneau et al., (2000) study, as 'peaks' of responses during extinction were occasionally quite high, and sometimes not within a general decline in response frequency, but as a stand-alone peak of a temporarily increased frequency of responding, with a period of very little or non-responding at either side of this 'peak'. Possibly this was due to the longer extinction sessions in the current study in which more peaks of responding were recorded. Also in the Tonneau et al., (2000) study, response rates were seen to initially increase in reinforcement conditions, but this effect was not observed in the current study. On the contrary, rates were seen to remain relatively stable across reinforcement sessions, despite sessions consisting of no more than 10 minutes.

The studies of Anger & Anger (1976) and Wickens & Miles (1954) found learning occurred in extinction sessions so that after some repetitions of alternating extinction sessions with reinforcement sessions, median responses made were approximately equal across the later extinction sessions. Results of the current

study also indicate that learning occurred with each presentation of an extinction condition. The first extinction condition responding persisted at a high rate for longer than in either Ext.2 or Ext.3. The total number of off-target pecks made in session one of Ext.1 was higher than previous reinforcement sessions, there after total off-target responses made in the first session of Ext.2 and Ext.3 were less than the number seen in previous reinforcement sessions. Ext.1 also had 'condensed' patterns, leading to higher proportion on-target values in Ext.1 than in any other extinction condition. This leads to the conclusion that responding in Extinction one was more stereotypical than responding in previous reinforcement sessions, and that responding became slightly more variable after this experience of the first extinction condition. Experience of an extinction condition did have a small effect on the proportion of on-target pecks in later reinforcement sessions, but this effect was not in any consistent across birds, so it cannot be said that extinction either increases or decreases variability in following reinforcement sessions.

The frequency distribution graphs for whole session show there is little effect of the alternating extinction and reinforcement conditions on overall structure (or patterns of pecks) in terms of frequency of distance of pecks from the square centre.

Other studies have suggested that after some experience of alternating extinctions, learned discriminations occur between reinforced and non-reinforced responses, thus resulting in consistently low rates of responding (Anger & Anger, 1976; Wickens & Miles, 1954). In the current study, there is little evidence for reinforced versus non-reinforced pecking discriminations, except for some sessions in Ext.2 and Ext.3, pecking quickly declined to zero, but then as was mentioned earlier, sometimes large peaks of pecks occurred in later parts of the session. There is a possibility the occurrence of peaks of pecks in the current study is a result of previously reinforced behaviours re-surfacing in extinction.

The current study used an FR5 schedule of reinforcement, while previous studies that found variability in extinction used a CRF schedule (i.e. Antonitis, 1951; Eckerman & Lanson, 1969). The study by Boren et al., (1978) found that an FR1 reinforcement schedule produced slightly more variation than an FR5 schedule, and that responding on FR schedules from FR5 or higher produced almost 100% stereotypy. The current study used an FR5 reinforcement schedule to ensure there would be enough responses to make a measure of variability, but also as a value low enough so as not to create unnecessary stereotypical conditions. The FR5 schedule resulted in many more responses than was anticipated, and this schedule was different to those of studies that found increased variability in extinction; so there is merit in repeating the current study using a CRF schedule.

The main aim of the current study was to observe the effects of extinction on the variability of behaviour in an attempt to gain further understanding of how behaviour varies in extinction. This aim was achieved; the results of the current study indicate that structures developed during conditioning do remain in extinction, and also while structures were found to remain, there was evidence for some increase in variability. These results are in agreement with the studies by Neuringer, et al. (2001), Nevin (1967), Goldberg (1959), and Margulies (1961), but are in disagreement with those studies by Antonitis (1951) and Eckerman & Lanson (1969).

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