The Further Analysis of Catania's Concept of the Operant.

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Abstract

Catania’s theory of the operant incorporated the continuous characteristic of behaviour, where the response distribution follows a normal distribution. That is, most responses fall within the reinforced range, a few responses persisted outside of the reinforced range. Three roosters and three hens were used as the subjects. A continuous reinforcement (CRF) schedule was implemented throughout both experiments of the study. In Experiment 1, the screen was divided into four quadrants. Only one quadrant was active in each condition and the active area shifted to a different quadrant across conditions. Each peck within the active quadrant was considered as a correct response, which results in reinforcement. Each peck outside the active quadrant was considered as an incorrect response, which results in extinction. In Experiment 2, the screen was divided into vertical strips. During Conditions 1 to 8, the consequences for the correct and incorrect responses are the same as Experiment 1. In Condition 9, the consequence for the incorrect responses changed from extinction to punishment (delay to reinforcement). That is, a 3 second red screen was followed with each occurrence of an incorrect response. It was found that the incorrect responses persisted during each condition of the two experiments for most birds. It was also found that most of the hens’ responses were correct responses by the end of each condition in Experiment 2. However, for all birds in Experiment 1 and the roosters in Experiment 2, most responses were not correct by the end of each condition. The findings of Experiment 2 also indicated that the changes in condition length, active area’s size, and consequence of the incorrect responses might have had some influence on the number of incorrect responses. Overall, the findings demonstrated behavioral continuity through exploring the distribution of response proportion when reinforcement was placed on the correct responses, and when extinction or punishment was placed on the incorrect responses. Thus, the study provided some empirical support towards Catania’s concept of the operant.

Acknowledgments

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Finally, to all my friends and family, thank you for being awesome.

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It is well recognized by many scholars that for behavioural studies to be scientific studies, the first step is to define the fundamental and observable behavioural units (e.g., Kolb, Jacobs, & Petrie, 1987; Skinner, 1938; Lee, 1988). This is because, for any scientific studies, the subject of interest should be sorted into applicable units before carrying out any procedures like measuring, manipulating, or theorizing. Thus, clearly identified observable units are the fundamental concern for behavioural science (Palmer, 2003).

Skinner (1938) proposed that the *operant* should be the fundamental unit in the behavioural science. When defining an operant (or a response class), Skinner (1938) focused on the functional relation between behavioural events (responses) and environmental events (consequences). That is, the responses that have occurred just before a specific environmental event should be considered as a response class or an operant. Skinner’s concept of the operant has been supported by many scholars (e.g., Staddon, 1967; Ferraro & Grilly, 1970; Glenn & Madden, 1995) and has been well adapted in behavioural research (Schwartz & Williams, 1972). Despite the popularity of Skinner’s concept in the field of behaviour analysis, it was claimed by several scholars (e.g., e.g., Baum, 1973, Catania, 1973; Palmer, 2003; Schick, 1971) that a functional operant is not always appropriate to apply in all situations, and there is a need to question the accuracy of Skinner’s definition of the fundamental unit of behavioral science (Schick, 1971; Palmer, 2003).

Schick (1971) stated that the way Skinner defined the operant is overly dependent on the reinforcement contingency. This over-dependency resulted in Skinner’s operant being too narrow to include responses that were manipulated by the reinforcement contingency but not functionally equivalent to the reinforced responses (Schwartz & Williams, 1972). This limitation of Skinner’s operant is reflected in several experimental studies (e.g., Williams and Williams, 1969; Schwartz & Williams, 1972). For example, in the study of Williams and Williams (1969), pigeons’ pecking on an illuminated key was placed on extinction and a food reinforcer delivery was contingent upon key illumination. According to Skinner’s operant definition, the key pecking and the responses other than the pecking should be classified into two separate response classes, as the former was followed by extinction and the latter was followed by reinforcement. However, the results showed that both of the reinforced responses (the non-pecking responses) and the non-reinforced responses (the pecking) were strengthened by the reinforcement contingency. Therefore, the findings of Williams and Williams’s (1969) study suggested that when Skinner’s operant concept was applied, all responses that were manipulated by the reinforcement contingency cannot be included into one response class.

Skinner made no reference to the continuous nature of behaviour when he constructed the concept of the operant, but he described the continuity of behaviour elsewhere (Cotton, 2012). Skinner (1953) stated, when a particular attribute of a response (e.g., force, rate or topography) was strengthened by reinforcement, all responses that shared any common attributes (e.g., the same level of force) with the reinforced responses would also be strengthened. In other words, reinforcement strengthens a continuous distribution of responses. The description of the behavioural continuity suggested that this continuous distribution of responses includes all responses that were manipulated by the reinforcement. Therefore, not including the continuity in the operant definition maybe the reason for Skinner’s operant being too narrow to include all responses that were manipulated by the reinforcement contingency.

Skinner (1953)’s explanation of the continuity suggested that the continuous nature of behaviour is closely linked with the behaviour attributes. Since the continuity was not included in Skinner’s operant, it is not surprising that the concept makes no reference to any behaviour attributes. However, Skinner (1938) did acknowledge the significance of behaviour attributes elsewhere. For example, the significance of response topography was presented by Skinner (1953) in his explanation of shaping. It was stated that the increased variability of topography is the outcome of placing the undesired behaviours on extinction during a shaping process. The increased variability of topography helps a response that is a closer approximation to the target response to occur, and then be strengthened by a differential reinforcement. The lack of acknowledgement of topography in Skinner’s (1938) operant definition implies that the topography should be considered during shaping but not during defining a response class.

It is clear that Skinner (1938) entirely ignored the topography when it comes to defining a response class, as he stated that how a rat presses the lever should not be a concern, as long as the lever is pressed. However, the importance of topography is clearly shown when human responses are manipulated by behavioural principals in applied settings. For example, the response of paying for a chocolate bar in a shop and the response of stealing a chocolate bar in a shop. One would say that the former is a socially appropriate response and the later is a socially inappropriate response, only based on the topography of the two responses, paying and stealing. This is because, humans often rely on the topography to decide whether a response is socially acceptable or not (Baer & Risley, 1987). Applied studies usually focus on increasing socially appropriate behaviour and decreasing socially inappropriate behaviour (Hudson, 1998). Thus, the responses of paying and stealing cannot be grouped into the same response class, as reinforcement should only be provided to increase the behaviour of paying, and extinction or punishment should only be provided to decrease the behaviour of stealing. However, according to Skinner’s operant, these two responses belong to the same response class, as both responses share the same function, which is getting a chocolate bar. This function-focused operant implies that the same consequence would be provided to both of the responses. However, it is certainly not appropriate to reinforce the behaviour of stealing or punishing the behaviour of paying.

Based on the discussion above, one may conclude that Skinner’s operant definition may not be appropriate to apply in experimental research and applied studies, as the definition does not include the continuity of behaviour, and only bases itself on the functional relationship between responses and consequences.

Since Skinner’s operant concept is based on his fundamental belief of operant learning (Schick, 1971), one may speculate that the reason Skinner constructed the function-focused operant concept could be closely related to his belief of operant learning. It is well known that Skinner’s concept of learning is heavily influenced by Thorndike’s (1911) law of effect. This law of effect is also widely supported by many other psychologists such as Hull, Spence, and Mowrer (Baum, 2002). The law of effect contained two fundamental concepts: firstly, response and reinforcement are seen as discrete and momentary events; secondly, the temporal contiguity between the response and reinforcement is critical to the level of strengthening, as a closer contiguity leads to a higher level of strengthening (Baum, 1973). The law of effect reflected Skinner’s belief of operant learning, that is, the determining factor in operant learning is the contiguity between the two separated events, response and consequence (Schick, 1971, Baum, 2002). Therefore, one may speculate that Skinner’s defining method of an operant, which is based on the functional relation between response and consequence, is heavily influenced by his belief of operant learning.

Baum (1973) questioned Thorndike’s law of effect, as he did not think responses and consequences should be treated as a series of discrete events. Baum pointed out that operant relations should be understood as the continuous interactions between responses and consequences. This is because, an organism interacts with its environment by producing the output (responses), the output then causes the environment to provide feedback (consequences) to the organism. This feedback process strongly indicates that behaviours flow through time, they are not momentary events that are usually considered in isolation. Based on the understanding of the feedback process, Baum (1973) proposed a law of effect that is fundamentally different to Thorndike's law of effect, as the former is based on the continuity between response and consequence, and the latter is based on the contiguity between response and consequence.

As mentioned above, Baum described operant relations as the continuous interactions between responses and consequences. Catania (1973) proposed a similar view, in which he claimed that an operant relation is established when the correlation changes between the distribution of response probability and the distribution of stimulus probability. Figure 1 illustrates the changes in correlation between the two distributions during different stages of a reinforcement contingency. The dashed line represents the distribution of stimulus probability; the solid lines A, B, and C, each line represent a hypothetical distribution of response probability in different stages of a reinforcement contingency. For example, the response parameter is the response topography in the measure of a bird's pecking location, and all pecks within the location of X to Y will lead to food delivery when the reinforcement contingency takes place. Before the reinforcement takes place, the distribution of response probability widely spread over a range of locations, as shown by line A. Thus, the correlation between the response probability distribution (line A) and stimulus probability distribution (the dashed line) is low, as very few responses were located in between X and Y. At the early stage of the reinforcement, the shape of the response probability distribution becomes more focused around the reinforced range of X to Y as shown by line B. Thus, the correlation between the distributions of response probability and stimulus probability increases. At the later stage of the reinforcement, the response probability distribution becomes narrower and more focused around the location of X to Y, as shown by line C. Therefore, the distributions of response probability and stimulus probability are highly correlated with each other.

The above example suggests that the changes in the distribution of response probability during different stages of a reinforcement contingency are able to represent the correlation changes between the distributions of response probability and stimulus probability. In other words, Figure 1 shows that an operant relation can be demonstrated through the changes in the distribution of response probability, which is presented by lines A, B, and C. Therefore, Catania's (1973) operant definition focused on the changes of responding that are caused by a contingency, and all behaviours that are manipulated by a contingency can be included into a response class. Figure 1 also shows that behavioural continuity is recognized in Catania's concept of the operant, since lines A, B, and C, indicate that a continuous response distribution of response location is strengthened when reinforcement takes place. Thus, Catania's operant not only includes the reinforced responses, the responses do not fulfill the reinforcement criteria but are still strengthened by the contingency which are also included into the same response class.

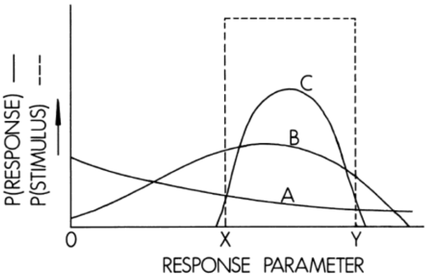

Figure 1. Catania’s hypothetical distribution illustrates the correlation changes between the distributions of response and stimulus probabilities. The distribution of stimulus probability is presented by the dashed line, the hypothetical distribution of response probability in various stages of a reinforcement contingency is presented by the solid lines A, B and C.

According to Catania’s operant concept, responses in an operant not only vary within a specific attribute (e.g., rate or topography) but also vary in function. Thus, the important characteristic of behaviour, response variance, is recognized in Catania’s operant concept. The importance of variance has been well acknowledged in the literature of behavioural selection (Donahoe, Burgos & Palmer, 1993). This is because, variation within an operant allows the operant to adapt to the changes of response contingencies (Glenn & Field, 1994). If a response class does not contain any response variations, the responses can only be reinforced through a single contingency, all responses in the response class would be going extinct when the reinforcement contingency changes (Donahoe, Burgos & Palmer, 1993). Therefore, it is critical to recognize response variance in the concept of the operant.

The advantage of applying Catania’s operant definition rather than Skinner’s operant definition can be clearly seen in the contingencies that do not contain the response-reinforcer contiguity. Hawkes and Shimp (1975) pointed out that not all reinforcement contingencies consist of the contiguity such as the contingencies in classical schedules. Within some contingencies, a reinforcer delivery may not be temporally contiguous with all the responses that produce it. The current understanding of this type of contingencies is limited and mainly derived from studying the interresponse-time (IRT) contingency (Hawkes & Shimp, 1975). In an IRT procedure, the reinforcers were delivered upon the occurrence of a specific temporal pattern of behavior. Thus, all IRT responses should be classified into one response class according to Skinner’s operant definition, as there is a functional relation between all responses and the consequence. However, Skinner (1938) also stated that the responses occurred just before a specific environmental event (the consequence) should be considered as a response class. Due to this emphasis on the response-reinforcer contiguity, not all IRT responses can be included into one operant. This is because, most responses in a reinforced temporal pattern are not temporally contiguous with the reinforcer. Therefore, Skinner’s operant concept is not appropriate to apply in any IRT contingencies, as the focus on the contiguity is not compatible with the focus on the functional relation between the response and the consequence (Hawke & Shimp, 1975). In contrast to Skinner’s concept, all the IRT responses would be included into one response class, according to Catania’s operant concept. This is because, all the IRT responses were established and manipulated into a specific temporal pattern by the IRT contingency. Therefore, an IRT contingency’s effects on responding can be completely recorded by applying Catania’s operant definition, but not by applying Skinner’s operant definition.

There are a few empirical studies that support Catania’s concept of the operant and his hypothetical distribution. Thus, Catania’s operant definition could be appropriate to use in behaviour analysis, and his hypothetical distribution could be an accurate prediction of a response distribution in various stages of a reinforcement contingency.

The findings of the study conducted by Silva, Yuille and Peters (2000) could be indirect evidence that support Catania's hypothetical distribution. Silva et al. illustrated the behavioral continuity through the two reinforcement schedules, FI 15-sec, and FR 5. The human subjects were required to move a cursor on a computer screen into an unknown and invisible target area in order to be reinforced by a beeping sound. It is found that during both of the FI 15s and the FR5 sessions, the movements of the cursor were all over the screen at the beginning of the session, and the movements became more organized and closer to the target area over the session. Silva et al. only presented the graphs to show the cursor’s movements on the screen. Thus, it is unclear whether the changes in the response distribution would be similar to what Catania had predicted in the hypothetical distribution. However, the process of cursor movements gradually focusing towards the reinforced area implied that the distribution of response locations narrowed down over the session, which seemed to be similar to the changes in response distribution that were presented in Catania’s hypothetical distribution.

The findings of Eckerman, Henz, Sern and Kowlowitz’s (1980) study could also have indirect evidence that supports Catania's hypothetical distribution. Eckerman et al. did not discuss the concept of the operant, as they only intended to examine the effect of differently sized shaping steps on shaping the pigeons’ pecking locations. In the study, pigeons’ pecking locations were shaped to move horizontally across the response area by shifting the reinforced region. The results showed that the distributions of response locations were in a shape of a normal distribution curve, with the higher response rates occurring in the reinforced region, and the lower response rates occurring in either side of the reinforced region. The response distribution in Eckerman et al.’s study appeared to be similar to what was presented in Catania’s hypothetical distribution. Therefore, Eckerman et al.’s findings suggested that Catania’s hypothetical distribution could be an accurate prediction of a response distribution in various stages of a reinforcement contingency.

Catania’s hypothetical distribution indicates that an operant relation is determined by the changes in the distribution of response probabilities, but the calculation method used for response probability was not specified by Catania. In Oliver’s (2009) investigation on Catania’s operant concept, he claimed that response rate is an appropriate measurement of response probability. Cotton (2012) further investigated Catania’s theory, but there was no discussion on the calculation method used for the response probability. Both response rate and response proportion were used to describe operant relations in Cotton’s study. Therefore, there is a need to discuss how operant relations should be interpreted through data.

Skinner (1938 & 1953) stated that response probability is the description of the strengthening effects that reinforcement has on responses, and response probability is calculated through response rate. Thus, Skinner treated response rate as the principal method to measure response strength, and response strength is Skinner’s way of describing operant relations between responses and consequences (Johnson & Morris, 1987). In other words, in Skinner’s point of view, response rate is the main measurement of operant relations. Skinner’s method of quantifying response strength has been well adopted in many of the behavioural studies (e.g., Smith, 1974; Staddon, 1975), but it also has been questioned and criticized by several authors (e.g., Coleman, 1981, Kling, 1971, Nevin, 1974; Baum, 2002 & 2004).

Apart from response rate, Skinner (1938) stated that operant strength can also be expressed by resistance to change. Skinner’s statement implied there is a correlational relationship between response rate and resistance to change. However, Nevin (1974) and Kling (1971) both pointed out that these two measurements of responding often lack a correlational relationship. For instance, Blackman (1968) examined the role of response rate and reinforcement frequency in conditioned suppression by using signaled shocks. It was found that when the response rate was held constant by employing the pacing schedules, the responses maintained by high reinforcement frequency were more easily suppressed than the responses maintained by low reinforcement frequency. It was also found that when the pacing schedules were used to establish the rats' high and low levels of response rate, and the reinforcement frequency was held constant, high response rates are more easily suppressed by the signaled shocks than low response rates. Similar to Blackman's (1968) findings, Nevin (1974) found that the high response rates are more easily suppressed by extinction or response-independent reinforcement than the low response rates, through training pigeons to peck coloured keys for food reinforcement using multiple VI schedules. Both Blackman's (1968) and Nevin's (1974) findings suggest that response rate and resistance to change are not always correlated with each other. Therefore, response rate is not always the appropriate measure of operant strength as Skinner has proposed (Nevin, 1974; Nevin, Smith & Roberts, 1987). In other words, it is not always ideal to use response rate to describe operant relations.

Baum (2002) pointed out that Skinner treated operant relations as the contiguity between the two discrete events, responses and consequences, and this view implies that the contiguity only exists in moments of time. Thus, in Skinner's point of view, operant relations should be understood as the momentary interactions between responses and consequences. Based on this understanding of operant relations, response rate is a suitable measurement of operant relations, as response rate describes the number of responses produced in a given length of time.

Although Catania did not discuss the method of quantifying operant relations, Baum's view on this topic should be considered, as Catania's (1973) and Baum's (1973) had a similar view on operant relations. According to Baum (1973), operant relations should be understood as the continuous interactions between responses and consequences. Based on this understanding of operant relations, Baum (2002) proposed that the description of operant relations should be based on the concept of time allocation. This is because, behaviours are choices, and a choice is allocating time to a certain activity instead of other activities (Baum & Rachlin, 1969). Therefore, responding is time management with a collection of activities, and time distribution can be quantified through response proportion (Baum, 2002). For example, a bird's pecking pattern on the screen is the bird's time distribution of pecking in various areas of the screen. The bird could spend 70% of its time pecking within the reinforced area, and 30% of its time pecking outside of the reinforced area.

In one's opinion, response proportion as the measurement of response relations is more compatible with Catania's operant concept than response rate. This is not only because Baum and Catania had a similar view on operant relations; but also because response proportion is able to reflect the changes in the distribution of response probability, and Catania (1973) stated that operant relations are demonstrated through these distribution changes.

The current study intended to further examine Catania’s concept of the operant based on the previous studies conducted by Oliver (2009) and Cotton (2012). Oliver (2009) autoshaped six hens to peck on a computer screen for food reinforcement on an FR 1 schedule. No visual cues were provided for discriminating between the active and non-active regions. It was found that when the size of the reinforced region was reduced, all the birds’ distributions of responses shifted to the active region, with the highest response rate produced within the active region, and the lower response rate produced outside of the active region. Thus, the study provided some supporting evidence towards Catania’s concept, as the findings suggested that the response distributions can be manipulated by the changes in the response contingencies.

Cotton (2012) also examined Catania’s concept of the operant by using six hens to peck on a computer screen for food reinforcement on a FR 5 schedule. When the active area moved horizontally across the screen over the conditions, it was found that the distribution of response locations shifted to the active area in each condition. The peak of the distribution curves usually centered over the active area, and the shape of the response distribution curves was similar to a normal distribution curve. It was also found that there were a considerable number of incorrect responses that had persisted during each condition. These findings suggest that the distributions of responses can be manipulated by the changes in the response contingencies, and the obtained response distribution curves were similar to what Catania presented in his hypothetical distribution. Thus, Catania’s hypothetical distribution may be an accurate prediction of a response distribution in various moments of a reinforcement contingency.

The current study builds on Cotton’s (2012) procedures to further examine Catania’s concept of the operant. The current study not only manipulated the location of the active area, but also manipulated the size of the active area, in order to examine Catania’s concept with various reinforcement criteria. Since Cotton (2012) reported the proportion of incorrect responses was consistently higher than the proportion of correct responses, the current study made a few changes to Cotton’s procedure, in order to decrease the response variability and increase the proportion of correct responses. Firstly, a continuous reinforcement (CRF) contingency was placed on the correct responses instead of a fixed ratio of five responses per reinforcement (FR 5), in order to decrease response variability in the study. This is because, several studies have found that intermittent schedules are more likely to produce responses with a higher level of variability than a CRF (e.g., Antonitis, 1951; Ferraro & Branch, 1968; Eckerman & lanson, 1969). Secondly, the contingency for incorrect responses was not only limited during extinction. A punishment contingency was also introduced, in order to decrease response variability. This is because, it was found that punishment usually has a stronger effect in reducing responding than extinction (Holz & Azrin, 1963; Uhl & Sherman, 1971).

The study hypothesized that Catania’s (1973) hypothetical distribution will be replicated. That is, when various response contingencies are implemented, the distributions of responses would always remain in a normal distribution curve, with responses being different in both function and topography in the measure of location.

Experiment One

Method

Subjects.

3 Black Australorp Roosters and 3 Brown Shaver Hens were used as the subjects for both experiments of the current study. Each bird was experimentally naive at the start of the study, and lived in the home cages where water can be consumed freely. All six birds were weighed daily and their body weights were maintained at approximately 80% of their free-feeding weight during the study. The birds were given wheat as a reinforcer in the experimental sessions; commercial laying pellets were given afterwards, as it was required to maintain 80% of their free-feeding body weight; and vitamins were provided once a week. Lighting of the birds' living area was running on an automatic 12:12 hour light/dark cycle.

Apparatus.

A 730 x 610 x 520 mm plywood experimental chamber had interior walls painted white; and a 235 x 310 mm LCD computer screen was placed 110 mm above the chamber floor, 48 mm deep into the right hand wall. The computer screen was surrounded by an infra-red touch panel, this device recorded the location of the birds' responses that were made on the computer screen. The screen was placed vertically to accommodate the height differences between roosters and hens. Under the screen, a 120 x 140 mm hole was cut out to allow access to reinforcers (grain) when the magazine was raised. Outside the chamber, a Dell Optiplex GX240 computer and USB interface were used for managing all experiment-related events and recording of the subjects' responses.

Procedure

Part 1: Magazine Training and Hand Shaping Procedures.

Each bird was magazine trained in the experimental chamber when the computer screen was off. The magazine was manually lifted up for approximately 3s with a 3s break in between each lifting so the birds had an opportunity to consume grain from the magazine. The training was considered complete when the birds ate the wheat from the magazine each time wheat was presented, ten consecutive times.

A manual shaping procedure was then used, the computer screen was on and white unless reinforcement was being delivered. A CRF reinforcement schedule was used in the hand shaping procedure, where one peck on any part of the white screen would lead to a 3 second wheat presentation. The hand shaping training was considered complete when the bird received 40 reinforcements.

Part 2: Experimental Procedure.

There were four conditions, all six birds responded on a CRF schedule throughout all conditions. Each condition contained six or seven sessions, each session was considered complete when either forty reinforcers were delivered or the session time of 1200 seconds elapsed. Only one quadrant of the computer screen was active in each condition, the active quadrant shifted to a different quadrant across conditions. Thus, each peck within the active quadrant would be considered a correct response, which resulted in the magazine being raised and wheat presented for 3 seconds. Also, each peck outside the active quadrant would be considered an incorrect response, and each incorrect response was placed on extinction (no reinforcement). As shown in Figure 2, Quadrant 1 was the active quadrant during Condition 1, Quadrant 3 was the active quadrant during Condition 2, Quadrant 4 was the active quadrant during Condition 3, and Quadrant 2 was the active quadrant during Condition 4. Within all sessions of Experiment 1, the whole computer screen was on and remained white. No visual cues were provided on the screen to assist with differentiating between active and non-active quadrants. When the magazine was raised each time, the computer screen turned black to signal the delivery of the reinforcer.

Condition 2. Quadrant 3.	**Condition 4.** Quadrant 2.
Condition 3. Quadrant 4.	**Condition 1.** Quadrant1.

Figure 2. The location of the active quadrant in Conditions 1 to 4.

Results

The results showed that the incorrect responses persisted throughout each condition for all birds, aside from Hen 7.4 in Conditions 1 and 3, and Hen 7.6 in Condition 1. Figure 3 presents the proportion correct for each bird across all sessions of Conditions 1 to 4. As seen in Figure 3, each bird's proportion correct was usually at its lowest point in the first session of a condition, then the proportion correct increased gradually with some fluctuations over the sessions, but it did not reach 100% by the end of the condition. An exception of the persistence of incorrect responses can be found in Conditions 1 and 3 for Hen 7.4, and Condition 1 for Hen 7.6. These two hens' proportion correct kept rising and eventually reached 100% accuracy in several sessions of Conditions 1 and 3. An exception of the increase of correct responses can be found in Conditions 2 and 4 for Hen 7.4, and Condition 2 for Hen 7.5. These two hens' proportion correct did not increase over the session, the proportion correct remained zero throughout the entire condition.

The results showed that the proportion correct's level of increase of varied across the conditions and subjects. The increase of the hens' proportion correct was generally faster than the increase of the roosters' proportion correct during Experiment 1. As observed in Figure 3, the hens' proportion correct usually reached above 0.75 by the end of each condition, but the roosters' proportion correct usually remained below 0.75. Rooster 7.1's proportion correct only had a mild increase in Conditions 1 and 3, the proportion correct was still below 0.50 by the end of the conditions. However, the proportion correct had a rapid increase in Conditions 2 and 4, the proportion correct reached well above 0.50 by the end of the conditions. Unlike Rooster 7.1, Rooster 7.3's proportion correct had a rapid increase in Conditions 1 and 3, the proportion correct reached well above 0.50 by the end of the conditions. However, the proportion correct had a mild increase in Conditions 2 and 4, the proportion correct was still below 0.50 by the end of the conditions. For Rooster 7.2's proportion correct, the level of increase became slower over the conditions. All hens' proportion correct had a rapid increase and reached above 0.90 in Conditions 1 and 3. However, in Conditions 2 and 4, the increasing level of proportion correct was varied among the hens. Hen 7.4's proportion correct remained at zero throughout Conditions 2 and 4. Hen 7.5's proportion correct remained at zero during Condition 2, but had a rapid increase during Condition 4. Hen 7.6's proportion correct had a mild increase in Condition 2 and did not reach above 0.50 by the end of the condition, but it had a rapid increase in Condition 4.

Figures 4 to 9 present each bird's distribution of response proportion across all four response areas in the first and last sessions of Conditions 1 to 4. These graphs showed that each bird's proportion distribution usually centered over an inactive quadrant in the first session, the distribution shifted to a different quadrant by the end of the condition, but did not always center over the active quadrant. For example, during Conditions 1 and 3, all the hens' proportion distribution shifted from an inactive quadrant to the active quadrant. However, during Condition 2, the peak of the distribution curve remained over an inactive quadrant (Quadrant 3) in the first and last sessions for each hen. In Condition 4, the peak of the distribution curve shifted to the active quadrant for Hens 7.5 and 7.6, but for Hen 7.4, the peak of the distribution curve remained over Quadrant 3 in the first and last session. Similar phenomenon was observed among the roosters. For example, the peak of Rooster 7.1's distribution curve was over an inactive quadrant during the first session of Conditions 2 and 4, and the peak was over the active quadrant during the last session. However, Rooster 7.1's distribution curve did not shift to the active quadrant by the last session of Conditions 1 and 3. The peak of the distribution curve shifted to another inactive quadrant in Condition 1, and the peak remained at the same inactive quadrant in Condition 3.

Figure 10 presents the response locations on the computer screen of each session of Condition 4, for Rooster 7.1 and Hen 7.6. These two birds' response locations are a fair representation of the response locations of other roosters and hens respectively. All birds' response locations in each condition are presented in Figures 25 to 30 in Appendix A. The results showed that the roosters' distribution of response locations was usually more widely spread than the hens' distribution. For example, in Condition 4, Rooster 7.1' distribution was more spread out than Hen 7.6's distribution as presented in Figure 10. At the beginning of Condition 4, Rooster 7.1's responses were widely spread across the four divided response areas; whereas Hen 7.6's responses were spread over two responses areas. Both birds' distribution of response locations eventually narrowed down towards the end of the condition, most responses were located in the top right quadrant, which is the active region (Quadrant 4).

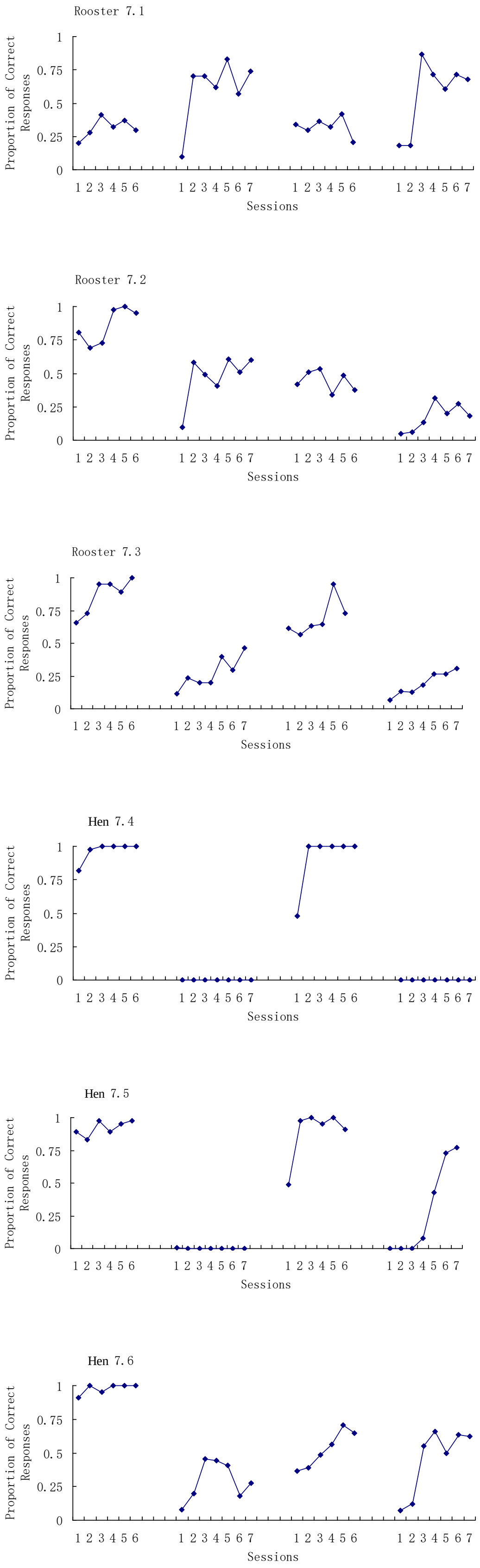

Figure 3. All birds’ proportion correct in every session of Conditions 1 to 4.

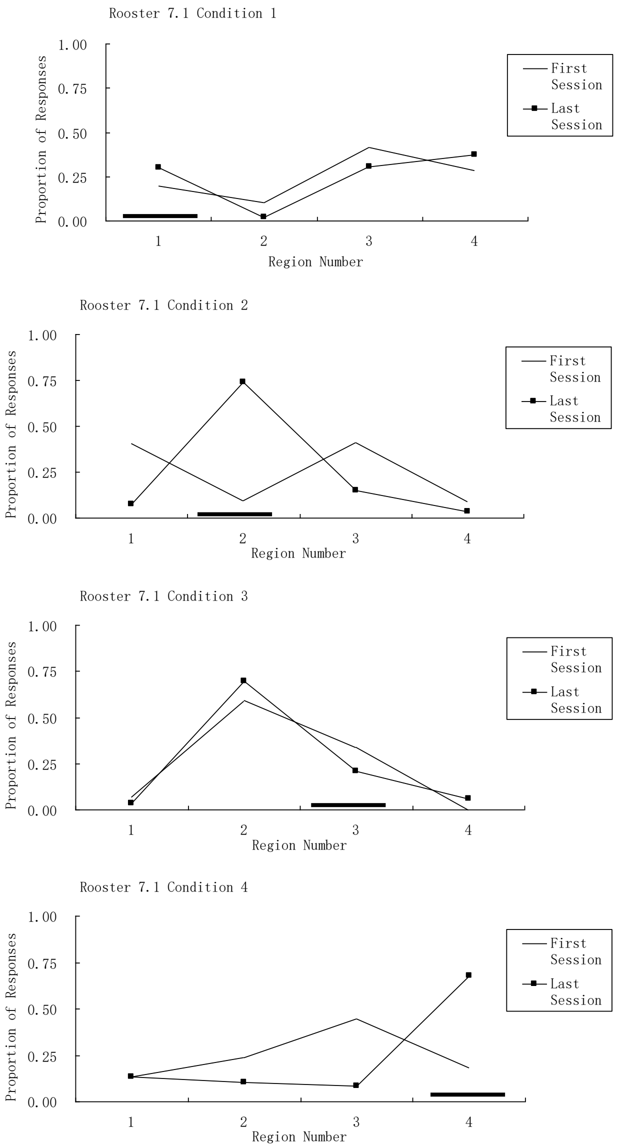

Figure 4. Rooster 7.1's distribution of response proportion in the first and last sessions of each condition of Experiment 1. The active area is shown as a black solid line.

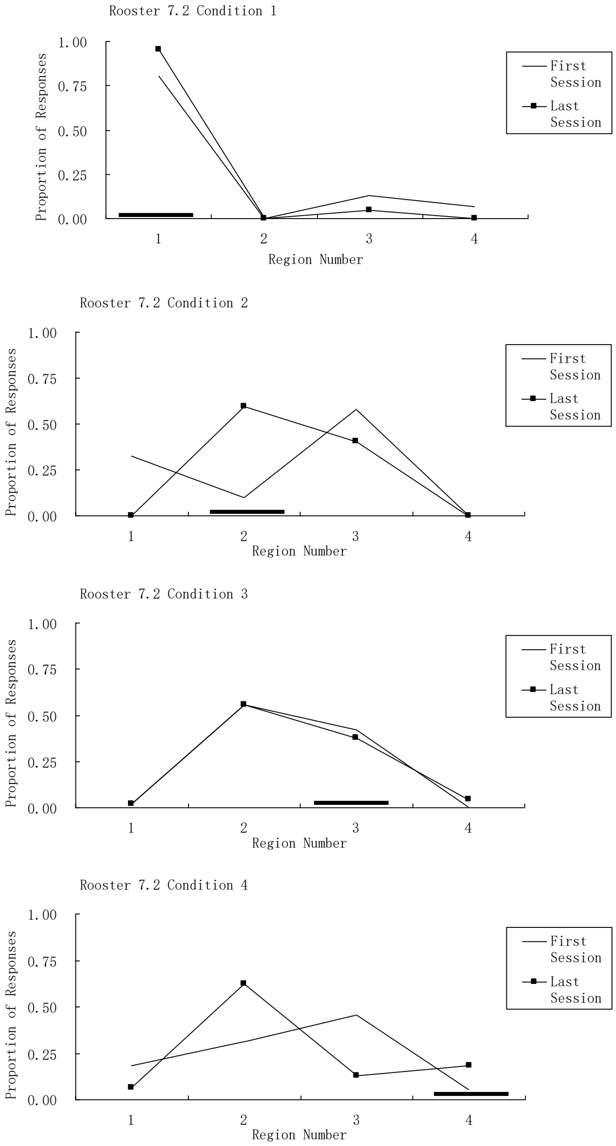

Figure 5. Rooster 7.2's distribution of response proportion in the first and last sessions of each condition of Experiment 1. The active area is shown as a black solid line.

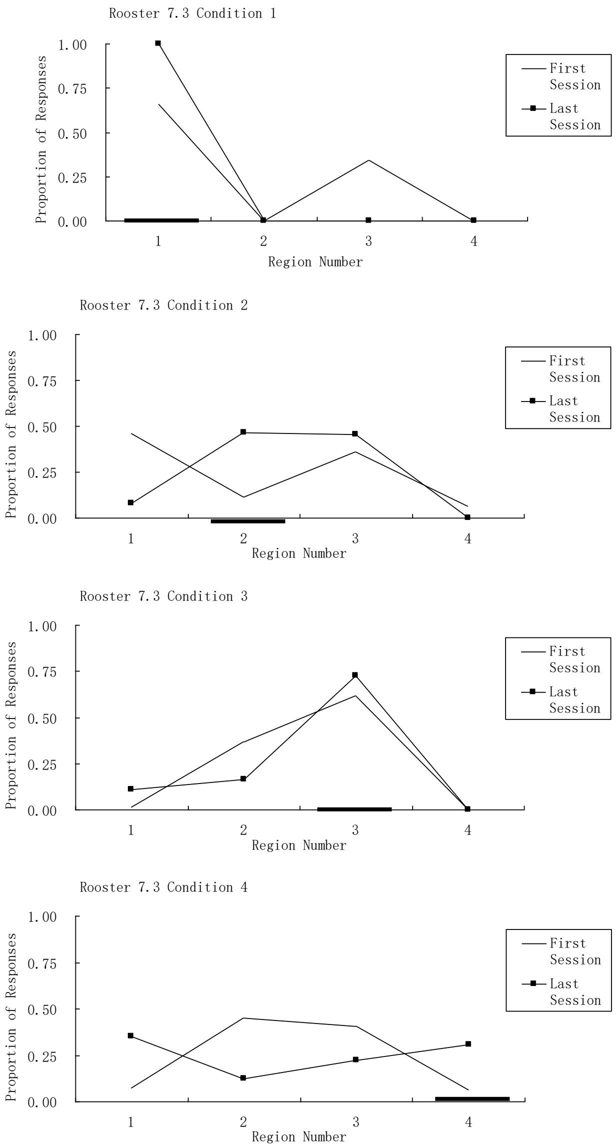

Figure 6. Rooster 7.3's distribution of response proportion in the first and last sessions of each condition of Experiment 1. The active area is shown as a black solid line.

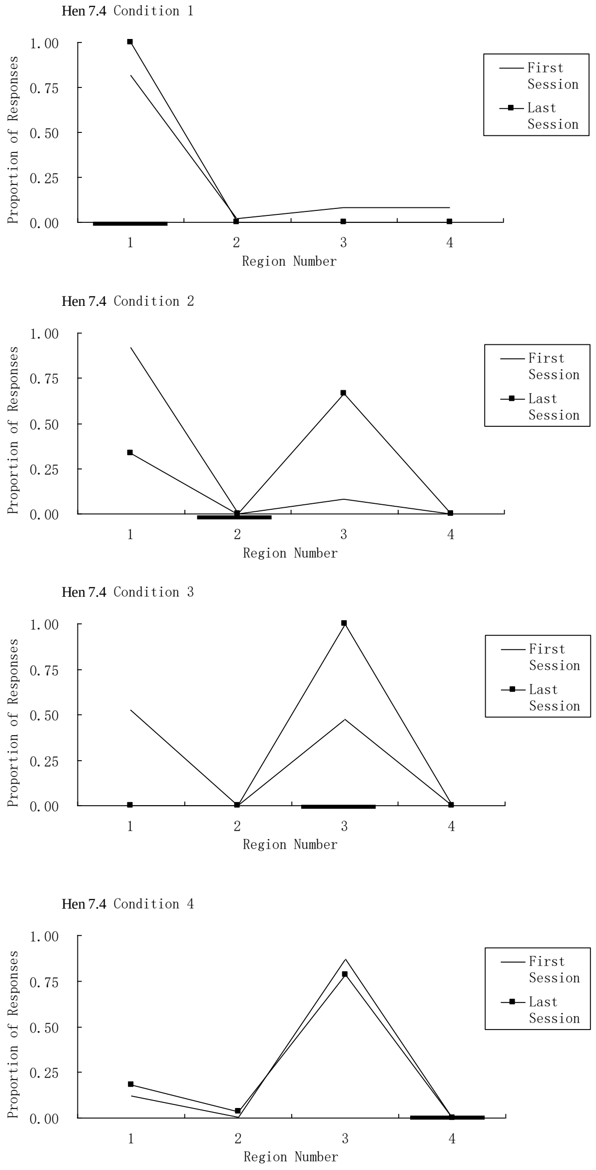

Figure 7. Hen 7.4's distribution of response proportion in the first and last sessions of each condition of Experiment 1. The active area is shown as a black solid line.

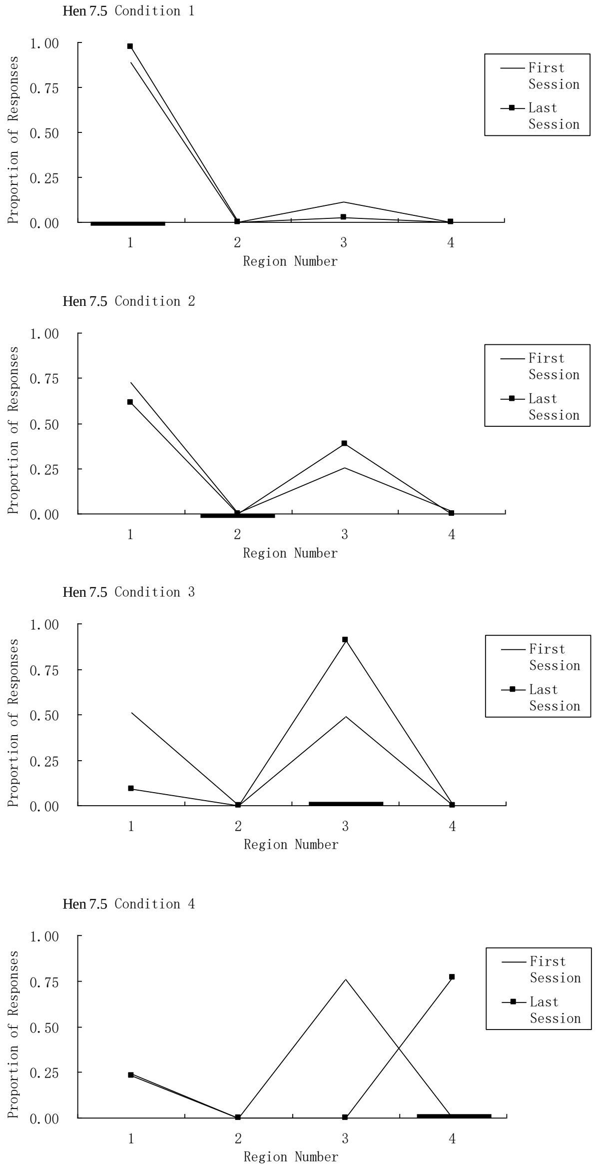

Figure 8. Hen 7.5's distribution of response proportion in the first and last sessions of each condition of Experiment 1. The active area is shown as a black solid line.

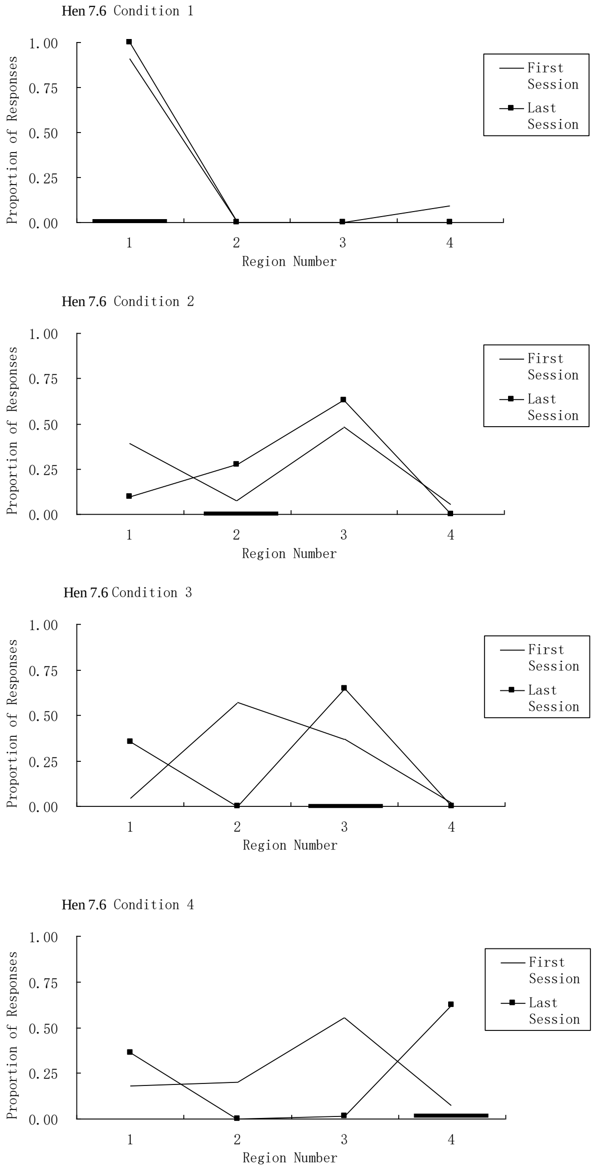

Figure 9. Hen 7.6’s distribution of response proportion in the first and last sessions of each condition of Experiment 1. The active area is shown as a black solid line.

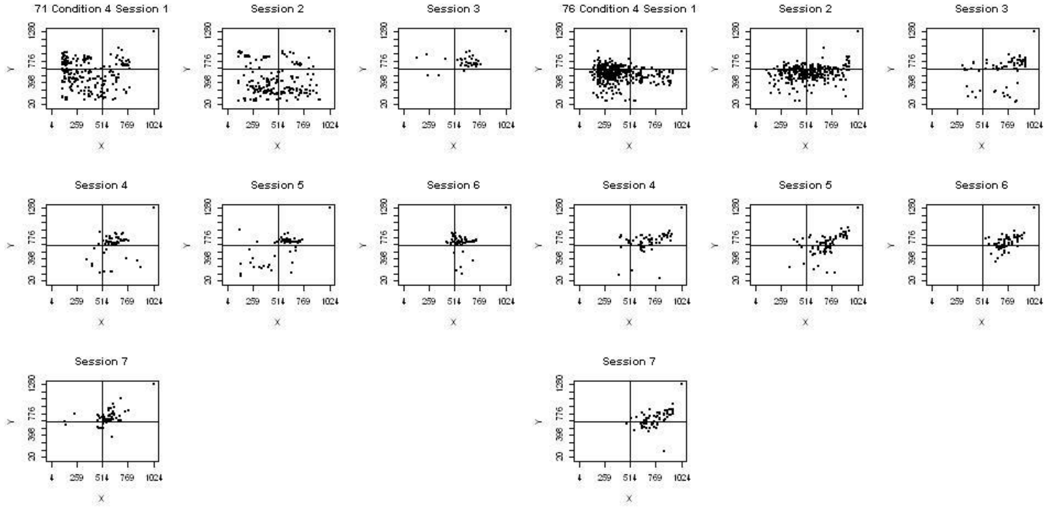

Figure 10. The response locations on the computer screen of each session of Condition 4 for Rooster 7.1 and Hen 7.6.

Discussion

This experiment partially adapted the procedure of Cotton's (2012) Experiment 1 in order to replicate Catania's hypothetical distribution and confirm Catania's concept of the operant. Thus, the experiment was designed to: Firstly, investigate whether the distribution of response proportion could be manipulated and controlled through the implementation of a reinforcement contingency. That is, whether the birds' proportion correct could be shifted to a target quadrant by changing the location of the active quadrant without applying any visual cues. Secondly, investigate whether incorrect responses would persist within each condition, even though the amount of incorrect responses would decrease over the sessions of each condition. In order to achieve a lower level of response variability and a higher proportion correct in comparison to Cotton's findings, this experiment adapted a CRF schedule rather than a FR 5 schedule.

According to Catania's hypothetical distribution, when the location of the active quadrant (the reinforced area) changed without applying any visual cues, each bird's distribution of responses would shift towards the active quadrant, with most responses being located within the active quadrant, and fewer responses being located within the inactive quadrants. However, the results showed that when the active area changed to a different location, each bird's distribution did not always shift to the active quadrant. That is, sometimes, more incorrect responses were produced than correct responses by the end of the condition. The findings suggested that Catania's hypothetical distribution was not replicated when the proportion distribution did not shift to the active quadrant, as most responses were not located within the active quadrant.

The current experiment did not obtain a higher proportion correct in comparison to the findings of Cotton’s Experiment 1. Figures 11 and 12 show each bird’s proportion correct during Cotton’s Experiment 1 and the current experiment. As presented in these figures, a steady growth of the proportion correct can be usually found across the conditions and subjects in Cotton’s experiment, however, the proportion correct’s growth was varied across the conditions and subjects in the current experiment. Also, the proportion correct in Cotton’s experiment is generally higher than the proportion correct in the current experiment by the end of each condition. The factors that might be contributing to the inconsistency of the proportion correct’s increase are explored next.

The results showed a huge variation in the hens’ increase in the proportion correct. For example, 100% accuracy occurred in several sessions of Condition 1 for Hens 7.4 and 7.6, and Condition 3 for Hen 7.4, whereas, 0% accuracy occurred throughout Condition 2 for Hens 7.4 and 7.5, and Condition 4 for Hen 7.4. It is thought that the screen placement in the chamber could be related to the huge variation in the hens’ proportion correct growth rate. In the current experiment, the 235 x 310 mm computer screen was vertically positioned, 150 mm above the chamber floor, which made the top two quadrants 305 mm above the floor (as shown in Figure 13). Since the hens’ average height was 252 mm, the hens needed to reach at least 53mm higher to make a response in any of the top quadrants. The results showed that the 0% accuracy only occurred during the conditions with the higher active quadrant, and the 100% accuracy only occurred during the conditions with the lower active quadrant. The results indicated that the top two quadrants could be too high for the hens to produce any responses. Therefore, the screen placement could be the contributing factor to the hens' varied proportion correct growth.

The roosters should be able to respond within the top two quadrants, as the quadrants were 305 mm above the floor, and the roosters' average height was 351mm. Thus, the inconsistency in the roosters' growth of the proportion correct was not related to the screen placement in the chamber.

The roosters' non-target behaviours could be related to the variation among the proportion correct's increase. It was observed that during Conditions 1 and 3, the roosters' non-target behaviors, such as pecking within the inactive quadrants which were located at the upper half of the screen, or standing closely to the screen, were often accidentally reinforced. This is because, when the non-target behaviours occurred, the rooster's feathers often accidentally touched the active quadrant which was positioned at the bottom half of the screen. These accidental responses were recorded as correct responses and led to reinforcer deliveries. However, the accidental responses made by the feathers were recorded as incorrect responses and they were not being reinforced during Conditions 2 and 4. This is because, these responses were usually located within the lower half of the screen, which were inactive quadrants during Conditions 2 and 4. Therefore, the inconsistency in the roosters' proportion correct's growth might be attributed to the indirect reinforcement of the non-target behaviours during Conditions 1 and 3.

The persistence of incorrect responses was found in both the current experiment and Cotton's Experiment 1. Boren, Moerschbaecher & Whyte (1978) and Tatham, Wanchisen & Hineline (1993) explored the relationship between reinforcement schedules and response variability. Cotton used the findings of these two studies to support her claim that the persistence of incorrect responses was not induced by the FR 5 reinforcement schedule. However, one does not think Boren et al.'s and Tatham et al.'s studies are able to support Cotton's point of view. This is because, different types of behaviours were recorded in Cotton's study, and in Boren et al.'s and Tatham et al.'s studies. The latter studies were only concerned with the reinforced responses. That is, only the behaviours that were varied in topography but still shared the same function were recorded. However, Cotton's study was concerned with both of the reinforced and non-reinforced responses. That is, that behaviours varied in both topography and function were recorded. Therefore, Boren et al.'s and Tatham et al.'s findings cannot support Cotton's claim. To my knowledge, the research around schedule-induced response variability does not include responses varied in both function and one particular dimension (e.g., Tatham et al., 1993; Boren et al., 1978; Doughty & Latta, 2001; Eckerman & Lanson, 1969). Therefore, it is unclear whether the persistence of incorrect responses in both the current and Cotton's studies were schedule-induced or not.

Overall, based on the results of Experiment 1, one would conclude that the experiment did not fully replicate Catania’s (1973) hypothetical distribution. Therefore, the findings of Experiment 1 cannot confirm Catania’s concept of the operant.

Cotton’s Experiment

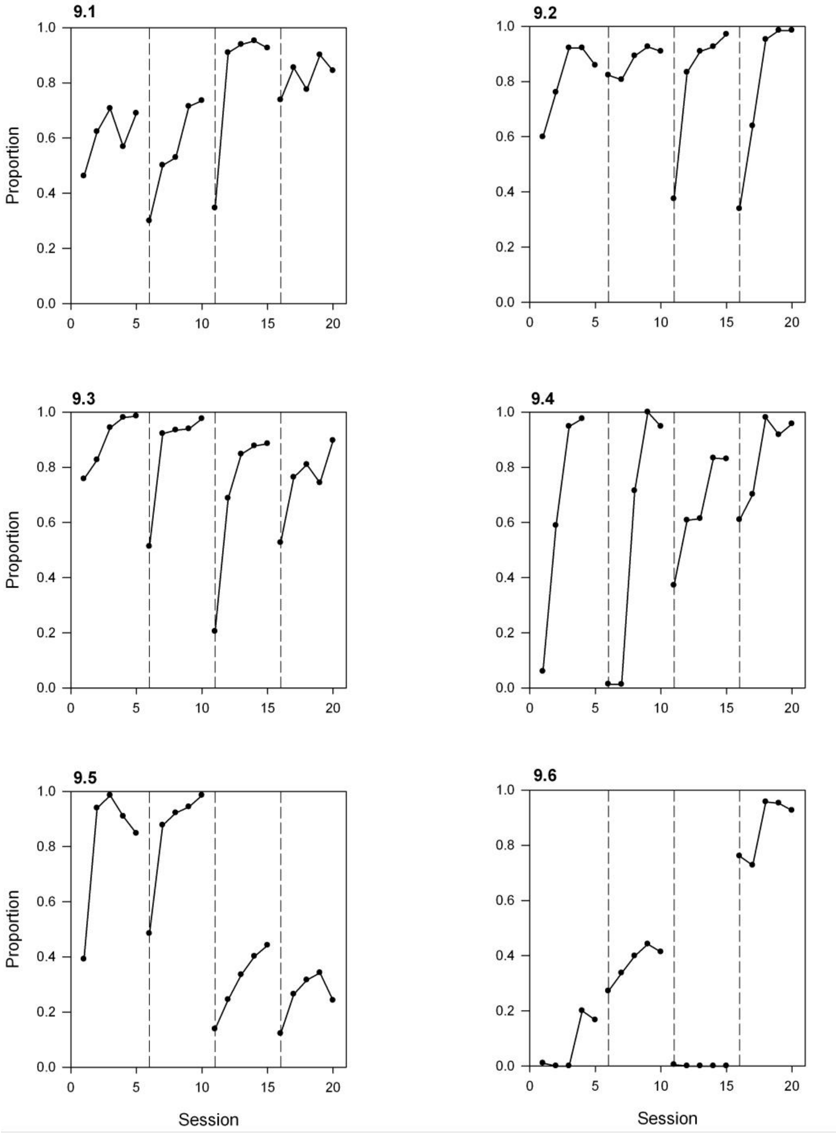

Figure 11. Each bird’s proportion correct in all sessions of Conditions 2 to 5 of Cotton’s Experiment 1.

Current Experiment

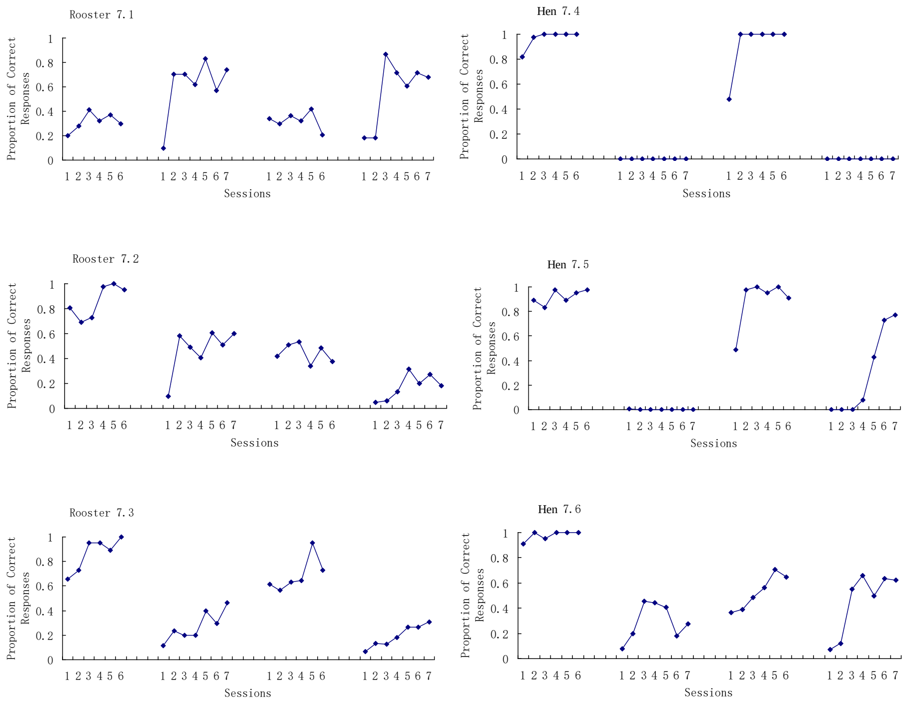

Figure 12. Each bird's proportion correct in all session of Conditions 1 to 4 of the current experiment.

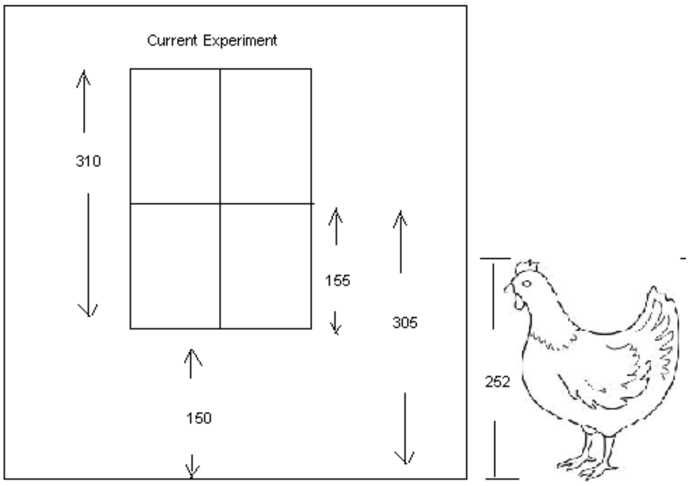

Figure 13. The screen placement in the chamber against the hens’ average height.

Experiment Two

Method

Subjects.

As in Experiment 1.

Apparatus.

As in Experiment 1.

Procedure

All conditions.

As in Experiment 1, all six birds responded on a CRF schedule. When the magazine was raised each time, the computer screen turned black to signal the delivery of the reinforcer. As in Experiment 1, throughout all conditions, the whole computer screen was on and remained white. No visual cues were provided on the screen to assist with differentiating between the active and non-active quadrants.

Conditions 1 to 4.

The computer screen was divided into four vertical strips and each strip was 55 mm wide x 310 mm long. Only one strip was the active area (the reinforced area) in each condition, and the location of the active area shifted to a different strip across conditions. As shown in Figure 14, Quadrant 1 was the active quadrant during Condition 1, Quadrant 2 was the active quadrant during Condition 2 and so on.

Conditions 5 and 6.

Condition 5 is a replication of Condition 4 with 32 sessions instead of 7 sessions, and Condition 6 is a replication of Condition 2 with 21 sessions instead of 7 sessions (see Figure 14).

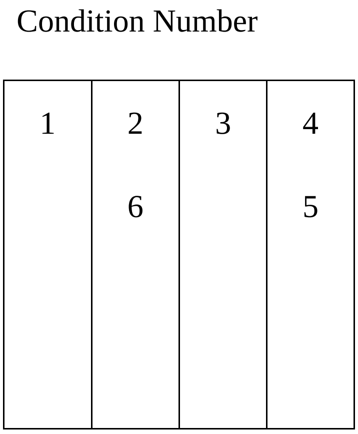

Figure 14. The location of the active area on the screen for Conditions 1 to 6.

Condition 7.

In Condition 7, the active area remained at the same location as Condition 6, but the width of the active area narrowed down from 55 mm to 30 mm (see Figure 15).

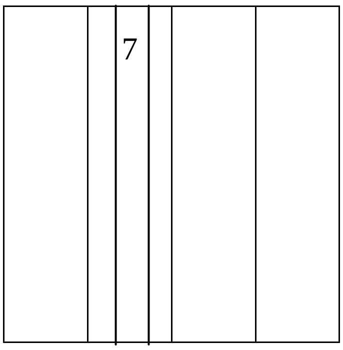

Figure 15. The location of the active area on the screen for Condition 7.

Condition 8.

For the hens, Condition 8 is exactly the same as Condition 7. For the roosters, however, the screen was horizontally divided into half in Condition 8. The top half remained active and the bottom half was inactive (see Figure 16).

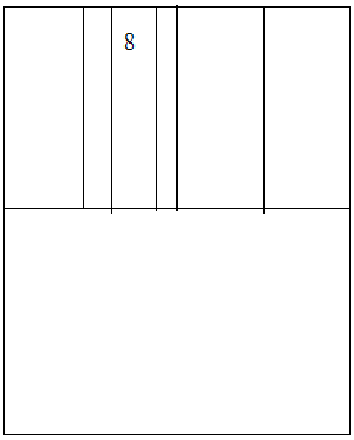

Figure 16. The location of the active area on the screen for Condition 8.

Condition 9.

Condition 9 is basically a replication of Condition 8, the response contingency for the incorrect responses (responses located outside the active area) changed from extinction to punishment. That is, with each occurrence of an incorrect response, a 3 sec red screen was followed instead of extinction.

Results

The results showed that the incorrect responses persisted throughout each condition for all birds, apart from Hens 7.4 and 7.5 in Condition 5. Figure 17 presents the proportion correct for each bird across all sessions of Conditions 1 to 9. As seen in Figure 17, each bird's proportion correct was usually at its lowest point in the first session of a condition, and then the proportion correct increased gradually with some fluctuations over the sessions, but did not reach 100% by the end of the condition. An exception to the persistence of incorrect responses is seen in Condition 5, Hens 7.4's and 7.5's proportion corrects kept rising and eventually reached 100% accuracy in several sessions.

The results showed that the rate at which the proportion correct increased varied across the conditions. In Figure 17, a rapid increase in the proportion correct was generally found in Conditions 1 to 6, however, a slow increase or no increase of proportion correct was generally found in Conditions 7 to 9. Thus, the proportion correct in Conditions 7 to 9 was generally much lower than the proportion correct of the previous conditions. For the hens, the proportion correct was mostly above 0.75 during Conditions 1 to 6, but the proportion correct was mostly between 0.50 and 0.75 during Conditions 7 to 9. Similar pattern in responding was seen for the roosters.

Figure 17 shows that the growth of the hens' proportion correct was generally faster and more consistent than the growth of the roosters' proportion correct. During Conditions 1 to 6, the hens' proportion correct consistently increased in a rapid pace, but the rate of the roosters' increasing proportion correct was not consistent. For example, for Rooster 7.1, a rapid increase of the proportion correct was found in Conditions 2 and 3, but a very slow increase of the proportion correct was found in Conditions 1 and 4. Also, during Conditions 7 and 8, a slow increase was consistently observed in the hens' proportion correct, but no increase was observed in the roosters' proportion correct, aside from Rooster 7.1's proportion correct in Condition 8, which had a slow increase. During Condition 9, the hens' proportion correct only had a slow increase, whereas, Roosters 7.1 and 7.2's proportion correct had a rapid increase throughout the condition. Rooster 7.3's proportion correct had a dramatic increase at first, and then the proportion correct dropped rapidly towards the end of the condition.

Figures 18 and 19 present the distribution of response proportion across each response area in the first and last sessions of each condition for Rooster 7.1 and Hen 7.4. These two birds' proportion distributions are a fair representation of the proportion distribution of other roosters and hens respectively. The remaining birds' proportion distribution is presented in Figures 31 to 34, which can be found in Appendix A. The results showed, for the hens, the peak of the proportion distribution curve was usually placed over an inactive area at the beginning of a condition, and the peak shifted to the active area by the end of the condition. However, this shift of the peak of the distribution curve was not consistently observed among the roosters. For example, Figure 18 shows that the peak of Rooster 7.1's distribution curve was placed over an inactive area in the first session of each condition, the peak of the curve did not shift to the active area in the last session of all conditions aside from Conditions 2, 3 and 9. Figure 19 shows, unlike Rooster 7.1, the peak of Hen 7.4’s distribution curve shifted from an inactive area to the active area during all conditions, aside from Conditions 2, 5 and 9. During Conditions 2, 5 and 9, the peak of the distribution curve was placed over the active region in the first and last sessions.

Figure 20 presents the response locations on the computer screen of each session of Condition 3, for Rooster 7.1 and Hen 7.4. These two birds’ response locations are a fair representation of the response locations of other roosters and hens respectively. All birds’ response locations in each condition are presented in Figures 35 to 64 in Appendix A. The results showed that the roosters’ distribution of response locations was usually more widely spread than the hens’ distribution. For example, in Condition 3, Rooster 7.1’ distribution was a lot more spread out than Hen 7.4’s distribution as presented in Figure 20. At the beginning of Condition 3, Rooster 7.1’s responses were widely spread across the four divided response areas; the distribution of response locations eventually narrowed down towards the end of the condition, spreading across two or three response areas. Unlike Rooster 7.1’s response distribution, Hen 7.4’s responses did not spread over the screen. Instead, the hen’s responses always gathered into a linear shaped cluster, they were placed horizontally at the bottom of the screen, and the cluster became narrower over the sessions.

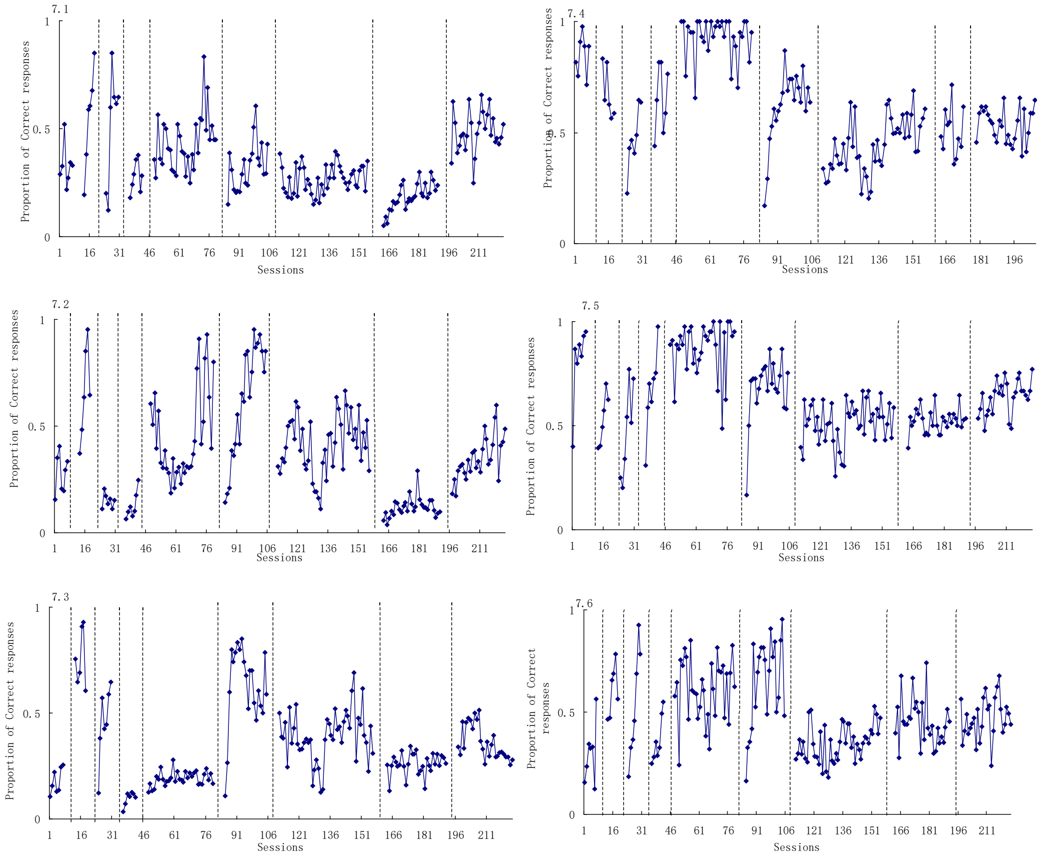

Figure 17. The proportion of correct responses for each bird across all sessions of Conditions 1 to 9 of Experiment 2.

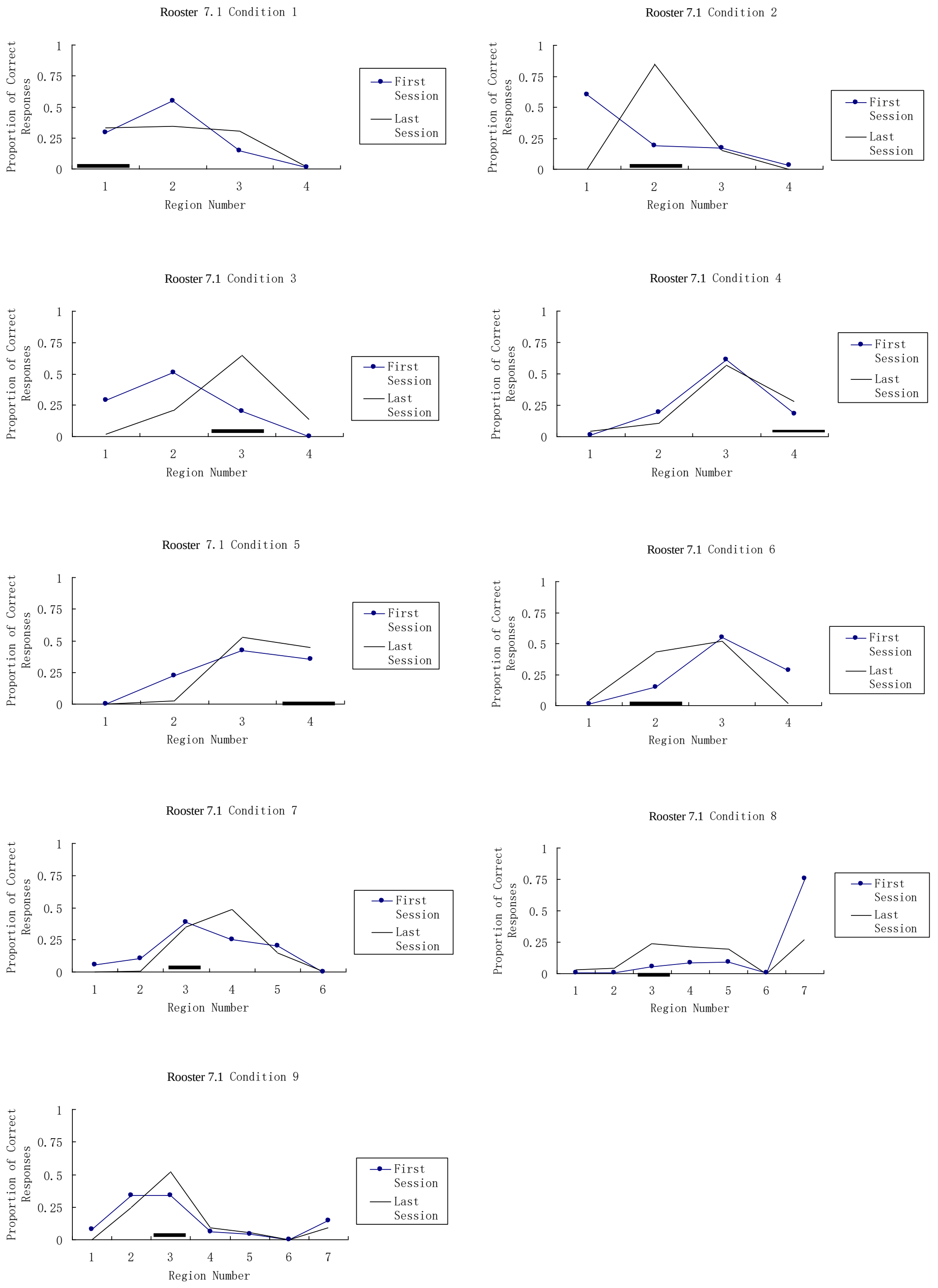

Figure 18. Rooster 7.1's distribution of response proportion in the first and last sessions of each condition of Experiment 2. The active area is shown as a black solid line.

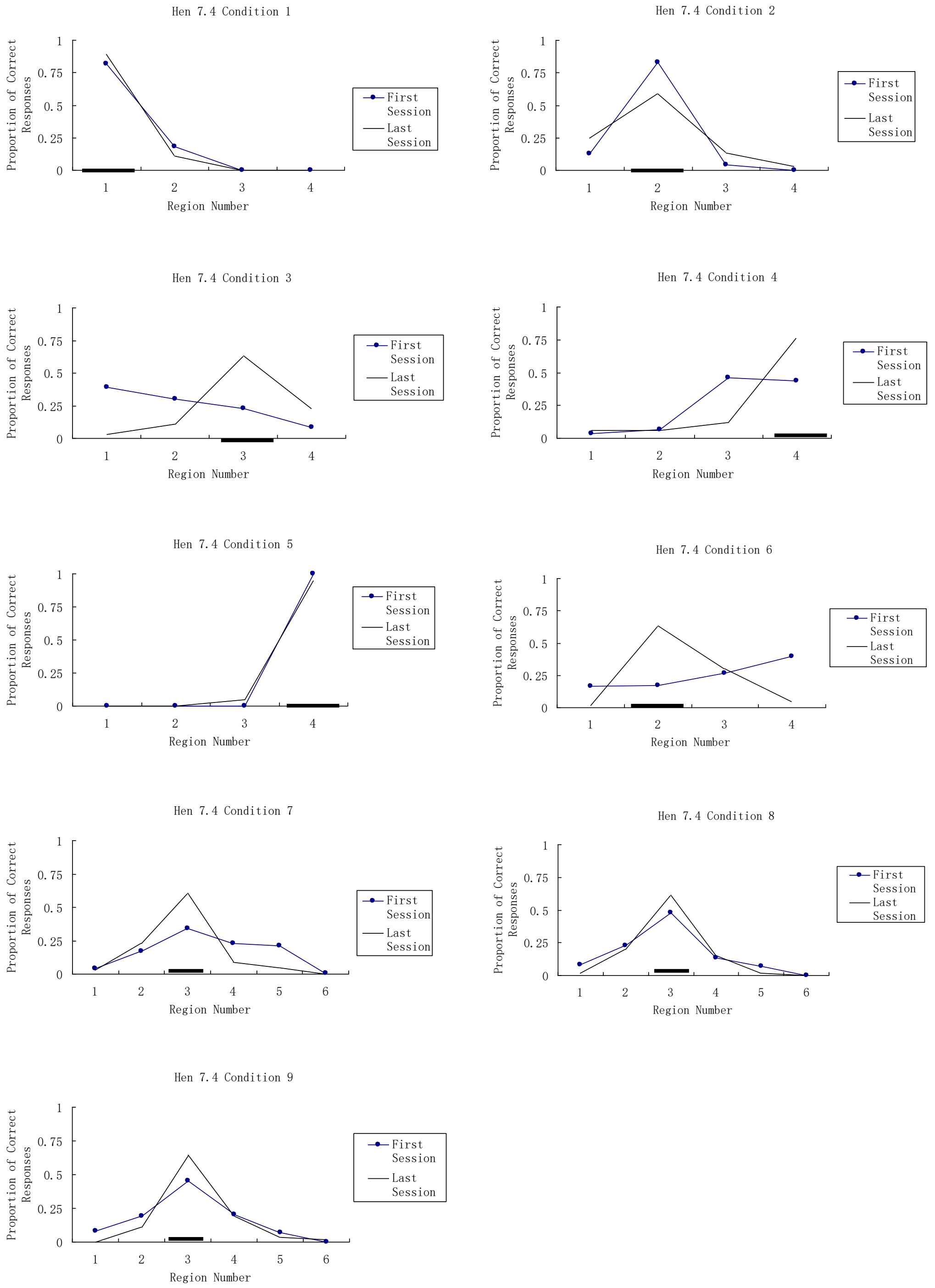

Figure 19. Hen 7.4's distribution of response proportion in the first and last sessions of each condition of Experiment 2. The active area is shown as a black solid line.

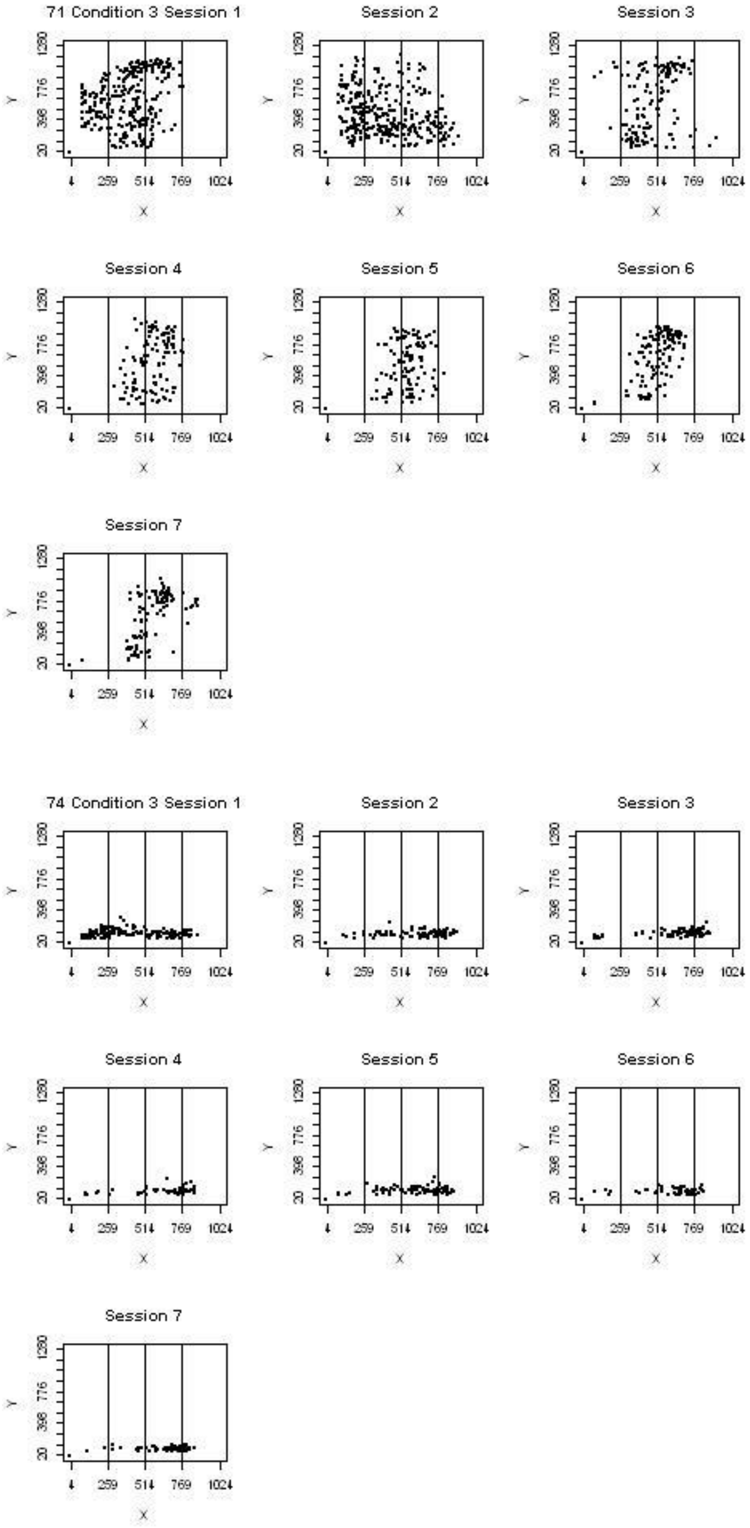

Figure 20. The response locations on the computer screen of each session of Condition 3 for Rooster 7.1 and Hen 7.4.

Discussion

Experiment 2 was designed to determine if Catania’s (1973) hypothetical distribution of responses would occur when different consequences were arranged for correct and incorrect responses. During Conditions 1 to 6, the criterion for reinforcement was manipulated by changing the active area’s location. During Conditions 7 and 8, the criterion for reinforcement was manipulated by changing the size (width or length) of the active area. Reinforcement was provided for all correct responses only during Conditions 1 to 8. However, during Condition 9, the consequence for incorrect responses was signaled-delay to reinforcement instead of extinction.

The results showed that, during Conditions 1 to 8, the hens’ proportion distribution consistently shifted to the active area, but the roosters’ proportion distribution did not always shift to the active area. By the end of each condition, the hens’ proportion distribution was usually in a shape of a normal distribution curve with the peak over the active area. However, the peak of the roosters’ proportion distribution was usually over one of the inactive areas as seen in Figure 21. Therefore, the findings suggest that Catania’s hypothetical distribution was successfully demonstrated with the hens, but was not clearly shown with the roosters when reinforcement was provided for correct responses only.

The results also showed that both of the hens’ and roosters’ proportion distribution shifted to the active area during Condition 9. By the end of the condition, all birds’ proportion distribution curves were in a shape similar to a normal distribution curve, with the peak placed over the active area. Therefore, the findings suggest that Catania's hypothetical distribution was successfully replicated with all birds, when the consequence of the incorrect responses changed from extinction to punishment.

As mentioned in the discussion of Experiment 1, the four quadrants created difficulties for the hens to make responses in the two top quadrants. In an attempt to overcome this problem, the screen was divided into vertical strips in Experiment 2. This is because, in each vertical response area, the responses located in both lower and higher positions would be recorded as responses in one area. It was hoped that, through this way of dividing the response areas, the hens' responding would not be restricted by the heights of the response areas. The results of Experiment 2 indicate that the hens did not have any difficulties in responding to the vertically divided areas. In other words, it appears that this arrangement of response areas overcame the problem in Experiment 1.

It was also mentioned in the previous discussion that the roosters' responding was not under the full control of the arranged response contingencies. This is because, the non-targeted behaviors (e.g., pecking within the inactive areas, or standing closely to the screen) were reinforced by accident when the feathers accidentally touched the active area. This was also observed in Experiment 2. Since the target behaviours and the non-target behaviours were both reinforced in the current experiment, it is thought that the roosters' responses were not under the full control of the arranged response contingencies. Therefore, the lack of contingency control over the roosters' responses might be the reason that Catania's hypothetical distribution was not produced by some of the roosters.

Cotton (2011) argued that the hens' response distribution would not narrow down any further, even when the conditions in her experiment became longer. However, the results of the current experiment suggest that, when the reinforcement criterion was manipulated in terms of the active area's location, the length of a condition may have some impact on the birds' proportion distribution. This effect of condition length can only be observed when comparing the results of Conditions 4 and 5, and the results of Conditions 2 and 6. This is because, Condition 5 was an extension of Condition 4 by 32 extra sessions, and Condition 6 was a replication of Condition 2 with 14 sessions that ran longer than Condition 2. In other words, the only difference between each condition pair was the condition length. Figure 22 shows that the hens' proportion correct increased further in the longer condition (Condition 6) than the shorter condition (Condition 2). Also, the hens' proportion correct increased further during the additional 32 sessions (in Condition 5) after Condition 4. These results suggest that a longer condition may lead to a narrower distribution of response proportion. Therefore, the findings of the current experiment appeared to be contradictory to what Cotton had claimed.

Several studies have found that extended training would decrease the variability of responses (e.g., Antonitis, 1951; Notterman, 1959; Vogel & Annau, 1973). For example, Antonitis (1951) explored the relationship between the level of response variability and the number of training sessions by training the rats to poke their nose on a 50cm response slot for food reinforcement. The findings suggested a decreasing monotonic function relating the rats' nose position variability to the number of reinforcements. Another example is the study done by Vogel and Annau (1973) in which the variability of response patterns was examined by training the pigeons to perform in an operant discrimination task. The results showed that the pigeons responded in a wide variety of patterns at the beginning of the training, but the variability of response patterns gradually decreased through continuous exposure to more training sessions.

Neuringer, Kornell, and Olufs (2001) explained the reduced response variability in longer conditions in the light of the evolutionary process. Neuringer et al stated that when the environment is more stable, an organism is more likely to retain the previously reinforced responses, whereas, in a more varied environment, an organism tends to produce completely different responses. The results of the current experiment appeared to support Neuringer et al's statement. The location of the active area shifted in each condition during Conditions 1 to 4, and the location of active area remained at the same place in Condition 5. The results showed that the birds' response variability in Conditions 1 to 4 was higher than the response variability in Conditions 5, as higher proportions correct were generally found in Condition 5 in comparison to Conditions 1 to 4 (as shown in Figure 23). Therefore, the findings indicate that the response variability may be related to the stability of the active area's location.

When the reinforcement criterion was manipulated in terms of the active area’s size (width or length), the findings suggest that the size of the active area may influence the birds’ response distribution on the screen. The impact of the active area’s size on the response distribution can only be explored when comparing the data of Conditions 5 and 6 to the data of Conditions 7 and 8. This is because, these conditions have similar condition lengths and the response consequences were the same, the only obvious difference among these conditions was the size (width or length) of the active area. Conditions 5 and 6 had a wider active area (55mm), whereas Conditions 7 and 8 had a narrower active area (30mm). Also, for the roosters only, the length of Condition 8’s active area was shortened to half of the active area’s length in Condition 7. Figure 24 shows that higher proportions correct were generally produced during the conditions with a wider active area (Conditions 5 and 6) in comparison to the conditions with a narrower active area (Conditions 7 and 8). Also, the roosters’ proportion correct decreased even further when the active area’s length was halved in Condition 8. These findings suggest that when the active area became smaller (e.g., the width became thinner or the length became shorter), the proportions correct decreased, which led to wider proportion distributions.

Overall, the results showed that the birds’ response distributions became wider when the active area became smaller, and the distributions became narrower when the conditions became longer. Therefore, one may conclude that the birds’ response distributions were under the influence of the size of the active area and the length of the conditions.

The results showed that the birds' proportion distributions in Conditions 7 and 8 were much wider than the distributions in Conditions 1 to 6. As mentioned previously, the smaller active area during Conditions 7 and 8 may have led to the wider proportion distributions. The literature also suggests that the wider distributions in Conditions 7 and 8 may be associated with the change in the relationship between the effect of shaping and the effect of extinction. Eckerman, Henz, Sern, and Kowlowitz (1980) claimed that the association between the effects of shaping and extinction on behaviour is a critical factor for shaping outcomes. This is because, more effective shaping would be achieved when the effects of extinction and shaping were pointing to the same outcome, as the extinction effect would be beneficial for the shaping process. However, shaping would be less effective when the effect of extinction was opposite to the effect of shaping, as the effect of extinction would not contribute towards the shaping process. Based on Eckerman et al.'s claim, an attempt to explain how the relationship between the effects of shaping and extinction impacted the shaping outcomes in Conditions 1 to 8 is presented next.

It is thought that the effect of extinction was beneficial to the desired shaping effect in Conditions 1 to 6 (excluding Condition 5). During each of these conditions, the shaping effect on responses was to shift the responses from the previously reinforced location to the currently reinforced location; the extinction effect was to increase the response variability (Eckerman & Lanson, 1969). The increased variability led to a more spread out distribution of response proportion, which increases the likelihood for more responses being reinforced as they are located within the current active area. Thus, the new reinforcement contingency could be established by increasing the response variability. In other words, the effect of extinction aided the shaping process during Conditions 1 to 6.

It is also thought that the effect of extinction was opposite to the effect of shaping in Conditions 7 and 8. The location of the active area did not shift to any new locations during Conditions 7 and 8, only the size of the active area became smaller than the previous condition. Thus, the responses were not shaped to shift from one location to the other. Instead, the distribution of response proportion was shaped to be narrower than the distribution of response proportion in the previous condition. In other words, the shaping effect on responses in Conditions 7 and 8 was to decrease the response variability. Since the extinction increased the variability (Eckerman & Lanson, 1969) and the shaping decreased the variability in Conditions 7 and 8, the effects of extinction and shaping were opposite to each other. Thus, the effect of extinction was adverse towards the shaping process (Eckerman et al., 1980).

As mentioned above, the relationship between the effects of shaping and extinction in Conditions 1 to 6 was different to the relationship between these two effects in Conditions 7 and 8. Since the relationship between the effects of extinction and shaping is a critical factor for shaping outcomes (Eckerman et al., 1980), one may speculate that in the current experiment, different relationships between the effects would lead to different shaping outcomes. That is, the narrower proportion distributions in Conditions 1 to 6 could be associated with the beneficial relationship between the effects of extinction and shaping, whereas, the wider distribution in Conditions 7 and 8 could be associated with the adverse relationship between the two effects.

The results showed that the number of incorrect responses decreased when the consequence for incorrect responses changed from extinction in Condition 8 to punishment (signaled-delay to reinforcement) in Condition 9. This finding suggests that the punishment procedure was more effective in reducing the number of incorrect responses than the extinction procedure. The use of signaled delay to reinforcement appeared to be an effective punisher in several studies (e.g., Pellon and Blackman, 1987; Flory and Lickfett, 1974; Lamas, E., & Pellón, R., 1995). For example, Pellon and Blackman (1987) studied the effects of signaled delay (10-s blackout), un-signaled delay (10-s) to food reinforcement and signaled-without-delay (blackout signals) on rats' schedule-induced drinking. The results suggested that both signaled and un-signal delays functioned as punishers for the rats' drinking behavior as it was reduced by both types of delays. However, the signaled-without-delay did not have any punishment effects on the target behavior as this type of delay did not reduce any drinking. More importantly, the results showed that the signaled-delay procedure was a more effective punisher for the target behaviour than the un-signal delay procedure.

Pellon and Blackman's findings can only be treated as indirect support to the current experiment's findings. This is because, the effect of signaled-delay was compared with the effects of un-signaled delay and signaled-without-delay in Pellon and Blackman's (1987) study, whereas in the current experiment, the effect of signaled-delay was compared with the effect of extinction. To one's knowledge, the literature on the effects of extinction and signaled-delay in reducing behaviour have not been directly compared with each other. Therefore, there is a lack of direct support for the current experiment's findings

The incorrect responses persisted throughout the whole of Experiment 2. The change of consequence (from extinction to punishment) for incorrect responses only diminished the amount of incorrect responses but did not entirely abolish this type of response. The possible reasons behind the persistence of the incorrect responses will be explored below.

The results showed that the incorrect responses persisted during Conditions 1 to 8 when the extinction contingency for incorrect responses was in place. This persistence of incorrect responses may be explained by the literature on the maintenance of learned behaviour during extinction. Several studies had shown that the previously learned response structure was unchanged, even though variability increased during extinction (e.g., Schwartz, 1981; Machado & Cevik, 1998 Neuringer, Kornell and Olufs, 2001). For example, Neuringer et al. (2001) examined the response stability and variability during an extinction procedure by studying the rats' response sequences on pressing one key and two levers. It was found that the hierarchy of response sequence probabilities did not change during extinction, even though the variability of response sequence increased. That is, the response sequences occurred in high probabilities during reinforcement and the sequence probabilities remained high during extinction. Based on the results, Neuringer et al. (2001) claimed that the hierarchy of sequence probabilities did not change during extinction as the learning was retained, even though the reinforcement was withdrawn. Therefore, when the extinction was in place for the incorrect responses in the current experiment, the persistence of the incorrect responses may be explained as the learned responses (i.e., the previously reinforced responses) retained.

Skinner's (1938; 1953) principle of induction may provide a theoretical explanation for the persistence of incorrect responses in Experiment 2. Induction occurs when responses that fall outside of the reinforced range are indirectly reinforced. These indirectly reinforced responses were strengthened because they shared common element(s) with the directly reinforced responses, not because they were in the same functional class. Therefore, the persistence of incorrect responses in the current experiment may be attributed to some incorrect responses being indirectly reinforced, since they shared common element(s) with the correct responses. These common elements could include: response force, body postures, or responding to the experimental equipment such as the computer screen. Since the directly reinforced responses are always strengthened more intensely than the indirectly reinforced responses (Catania, 1971; Schick, 1971), this may be the reason that the proportion correct was generally higher than the proportion of incorrect responses, as shown in the results.

The theoretical explanation for the persistence of the incorrect responses could also be related to biological evolutionary principles. Many studies explored the possible parallels between behavioural principles and organic evolutionary principles (e.g., Glenn and Madden, 1995; Glenn and Field, 1994; Donahoe, Burgos and Palmer, 1993). Reinforcement as a behavioural selection process which parallels natural selection has been argued for decades by many behavioural scholars (e.g., Campbell, 1956; Skinner, 1953; Staddon, 1973). According to Darwin and Wallace (1958), natural selection is a significant part of the species' evolutionary process, and natural variations play an important role in the selection process. This is because, a few variations may increase the possibilities to survive and reproduce, even though most variations are not critical to the individual's survival and reproduction. Similar to the theory of biological evolution, in the behavioural science domain, behavioural selection is considered as an important part of operant's evolutionary process (Glenn, Ellis and Greenspoon, 1992).

Catania (1973) named a population of responses that is generated by reinforcement as a functional operant. He pointed out that some responses within a functional operant carry certain characteristics that fall outside the criteria of reinforcement. According to Glenn and Field (1994), these "non-criteria" characteristics are considered variations among individual responses of a response class. As mentioned above, behavioural selection is generally considered as a similar process to natural selection. Thus, in one’s opinion, the role of behavioural variations in behavioural selection should be similar to the role of natural variations in natural selection. That is, behavioural variations should be critical to the process of behavioural selection. During a selection process, when a reinforcement criterion is manipulated, the variations (i.e., the “non-criteria” characteristics) that fit the new criterion may increase the possibilities to maintain and generate more responses that contain the variations. Therefore, the persistence of the responses which contain the “non-criteria” characteristics (i.e., the incorrect responses) in the current experiment is attributed to the fact that these responses are critical in maintaining and generating individual responses during reinforcement. In short, the existence of the incorrect responses is important to the process of behavioural selection.

In conclusion, the findings of Experiment 2 suggest: Firstly, when reinforcement was provided upon the occurrence of a correct response, and extinction was implemented on each occurrence of incorrect response, Catania’s hypothetical distribution could be produced with the hens but not with the roosters; Secondly, when the consequence of the incorrect responses changed from extinction to punishment, Catania’s hypothetical distribution was successfully replicated through all the birds’ data; Thirdly, the spread of the proportion distribution were under the influence of the size of the active area, the length of the conditions, and the relationship between the effects of shaping and extinction.

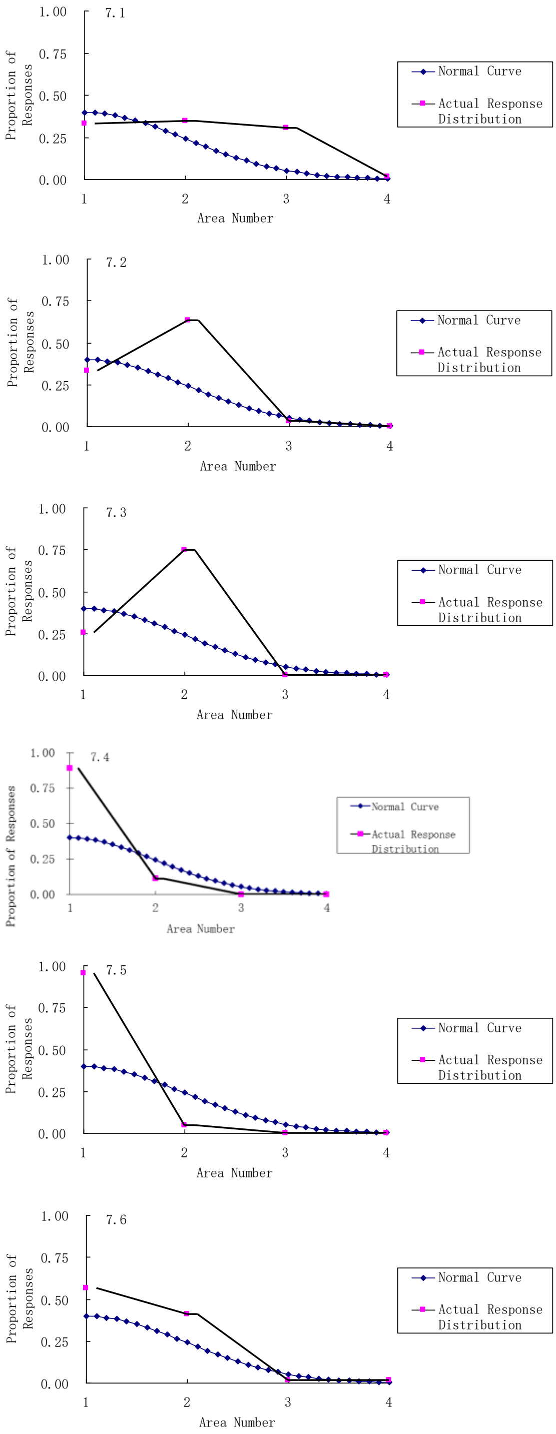

Figure 21. All birds’ distributions of response proportion in the last session of Condition 1 plotted against a normal curve. Area 1 is the active area.

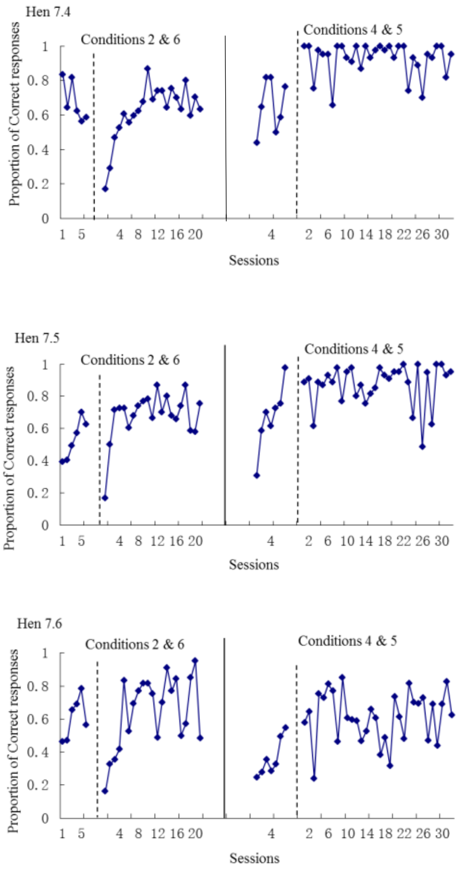

Figure 22. The proportion of correct responses for Hens 7.4 to 7.6 across all sessions of Conditions 2 and 6, and Conditions 4 and 5 of Experiment 2.

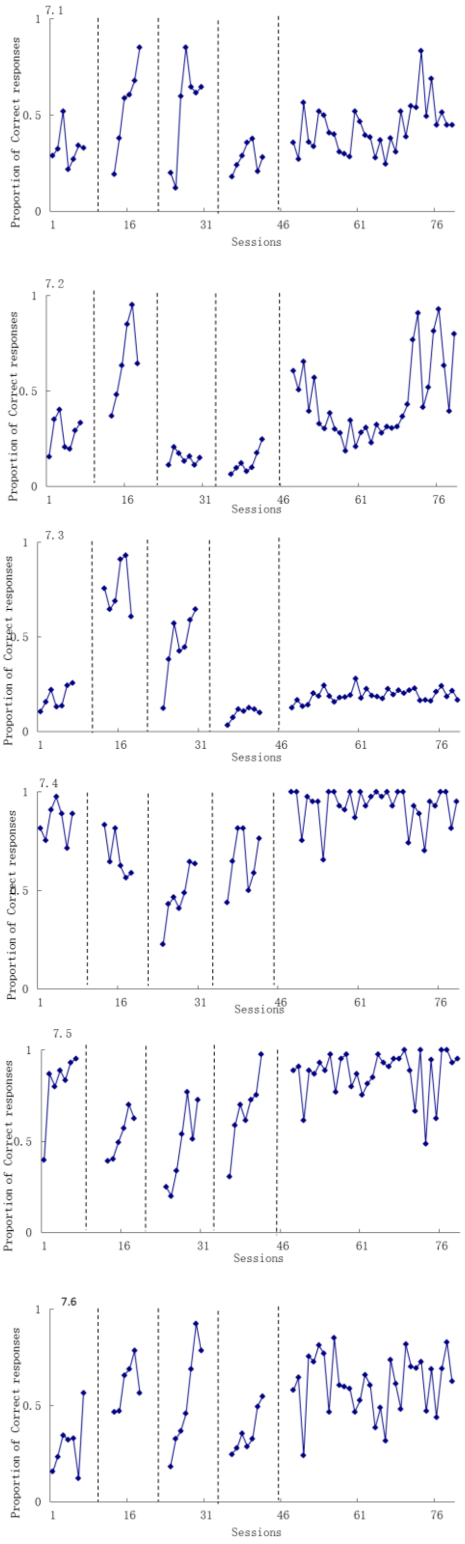

Figure 23. All birds' proportion of correct in all sessions of Condition 1 to Condition 5.

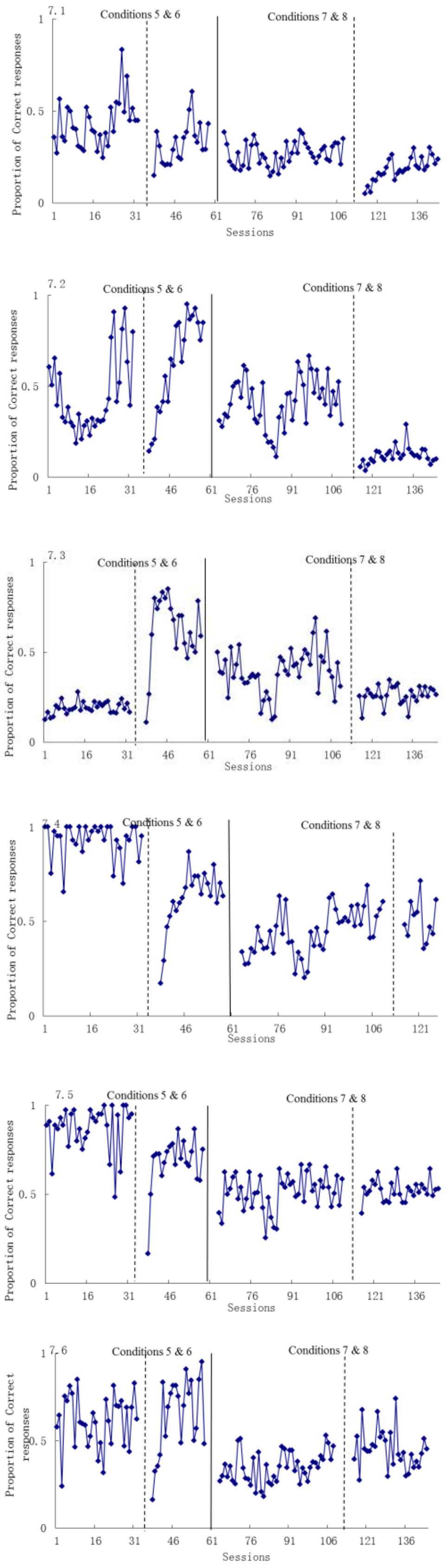

Figure 24. All birds' proportion of correct across all sessions of Conditions 5 and 6, and Conditions 7 and 8 of Experiment 2.

Conclusion

As previously stated, in the findings of this study, the continuous nature of behavior was demonstrated only among the hens when a reinforcement contingency was provided. However, when a reinforcement contingency and a punishment contingency were both in place, the continuous nature of behavior was demonstrated among all birds. Also, it was found that the size of response distribution maybe related to the size of the active area, the length of the conditions, and the relationship between the effects of shaping and extinction.

The limitation of this study lies in the data recording device's inability in differentiating the topography of the responses that were detected by the screen. For example, pecking or feather touching at the screen, these two responses have different topographies. However, both responses would be treated as one type of response by the data recording device. In order to prevent such an issue, future studies could start with disabling the lower half of the screen to reduce the chance of feathers touching the screen. Future studies also could avoid using roosters as experimental subjects, as it was found that the hens' feathers did not touch the screen during the current study.

In order to further examine Catania's operant theory, future studies could examine the effect of other consequences for incorrect responses. For example, applying white noise as mild punishment, or, providing visual or audible signals when the responses fall outside of the reinforcement criteria. Also, future studies could investigate responses on other dimensions such as force, rate, or duration.

This study illustrates the benefit in applying Catania’s operant definition, as the impact of contingencies on responding can be recorded. In this study, a response class contains a whole response distribution in terms of response location that is manipulated by the consequence. Thus, the significant role of behavioural continuity is recognised in the process of analysing behaviours through applying Catania’s operant theory. This study illustrates the disadvantage of applying Skinner’s operant definition, as the full effects of contingencies on responding cannot be recorded through a function-based operant. Since the traditional defining method of the fundamental unit may not be appropriate to apply in all situations, the behavioural principles that are built on the fundamental unit (such as reinforcement, punishment, shaping etc.) could all be re-investigated.

This thesis concludes that Catania’s operant concept maybe appropriate to apply in empirical analysis, as the definition of operant incorporates the continuous nature of behaviour, and behaviours and consequences are not treated as discrete and momentary events.

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Appendix A.

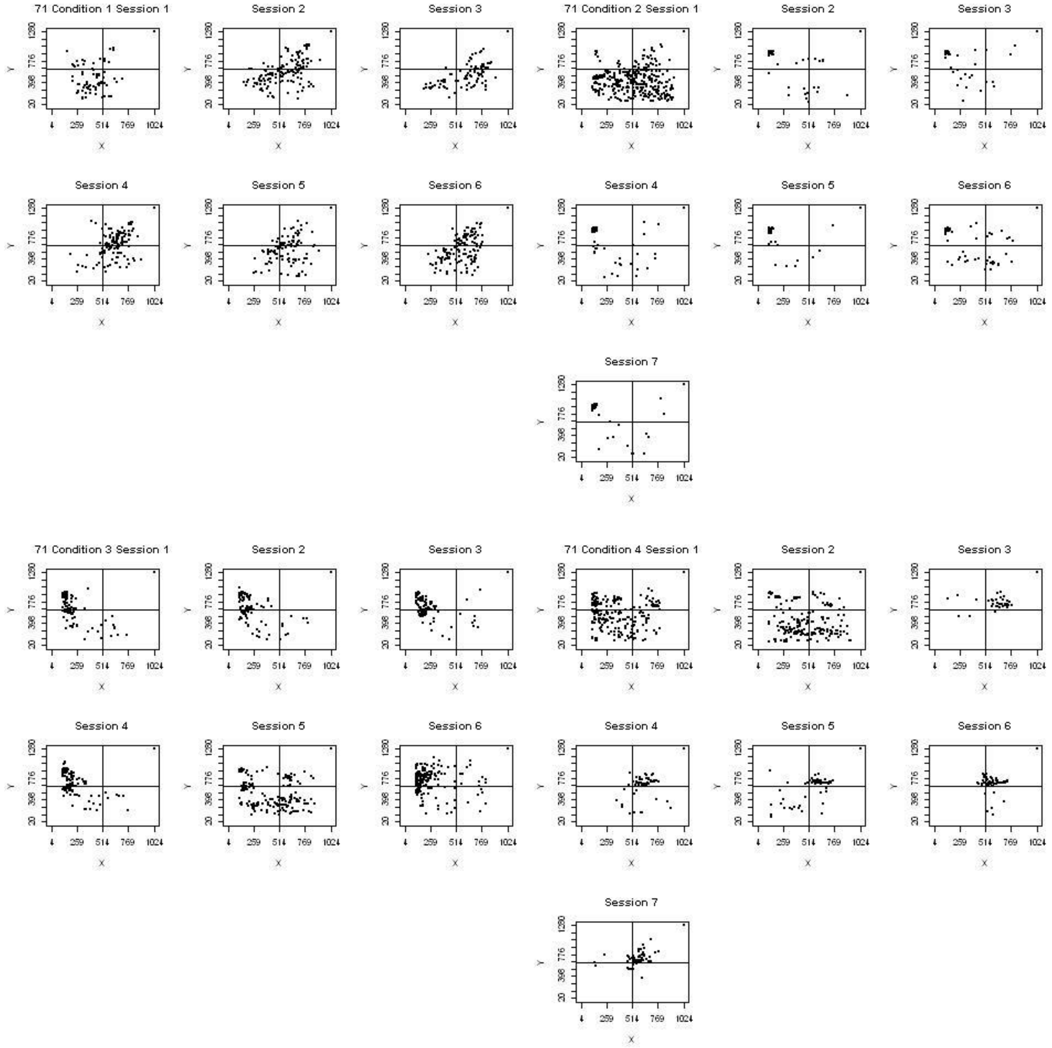


Figure 25. Rooster 7.1’s response locations in each session of Condition 1 to Condition 4.

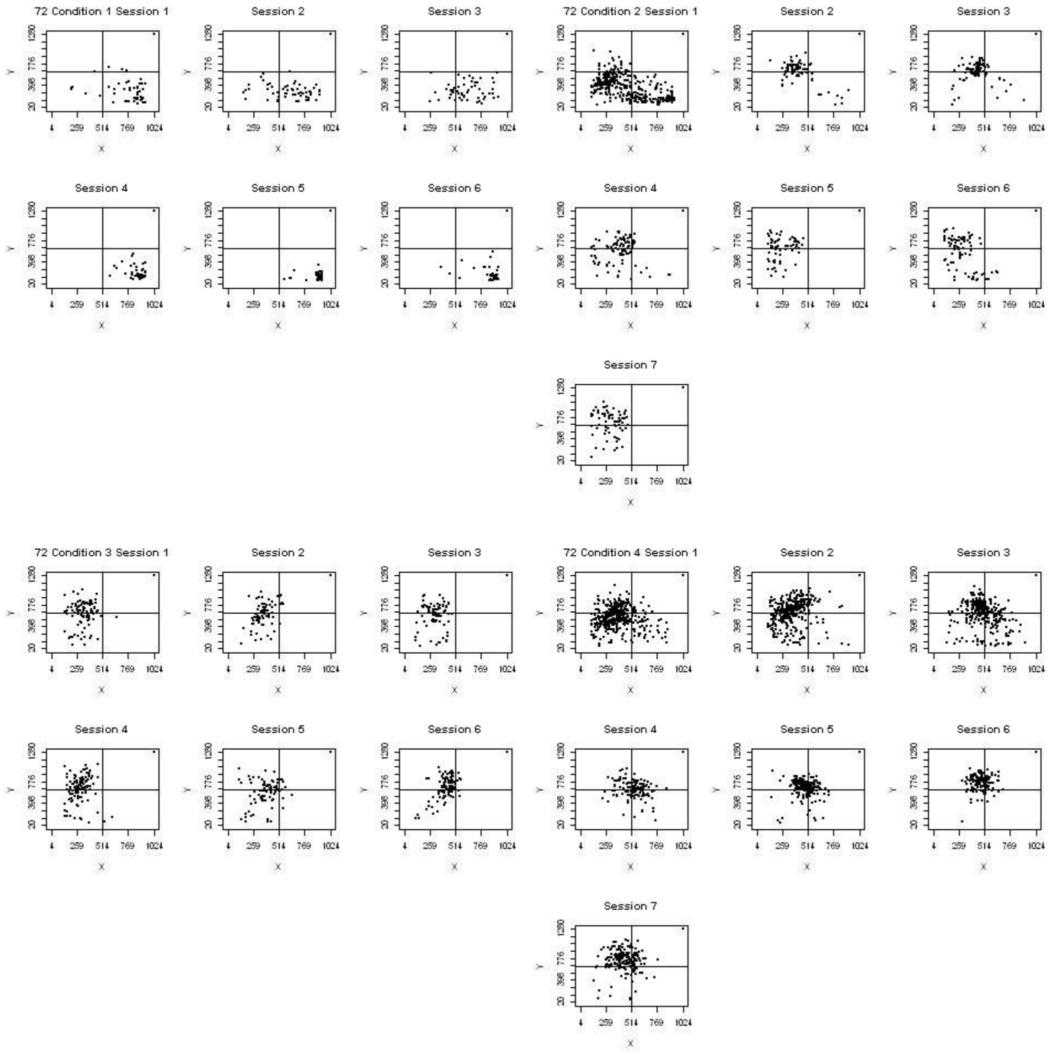


Figure 26. Rooster 7.2’s response locations in each session of Condition 1 to Condition 4.

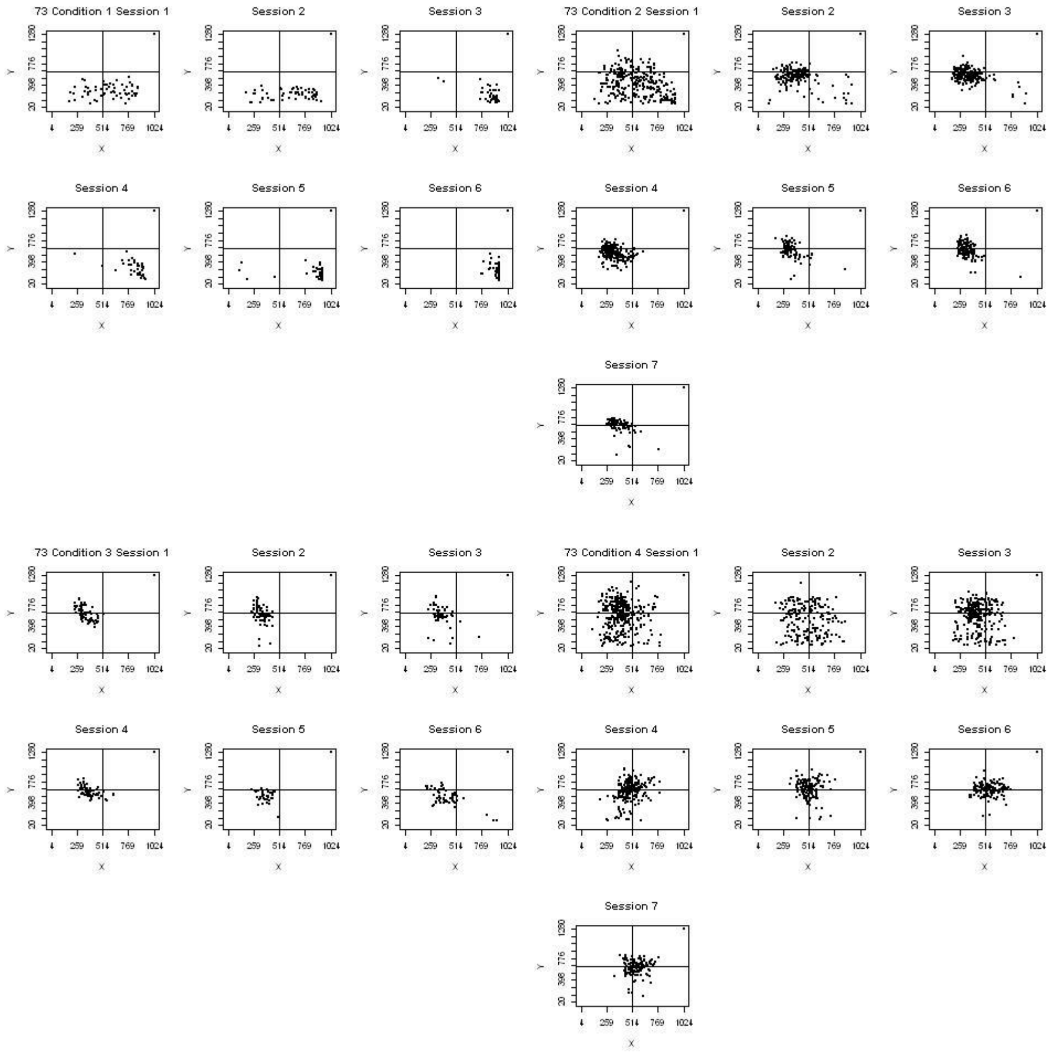


Figure 27. Rooster 7.3's response locations in each session of Condition 1 to Condition 4.

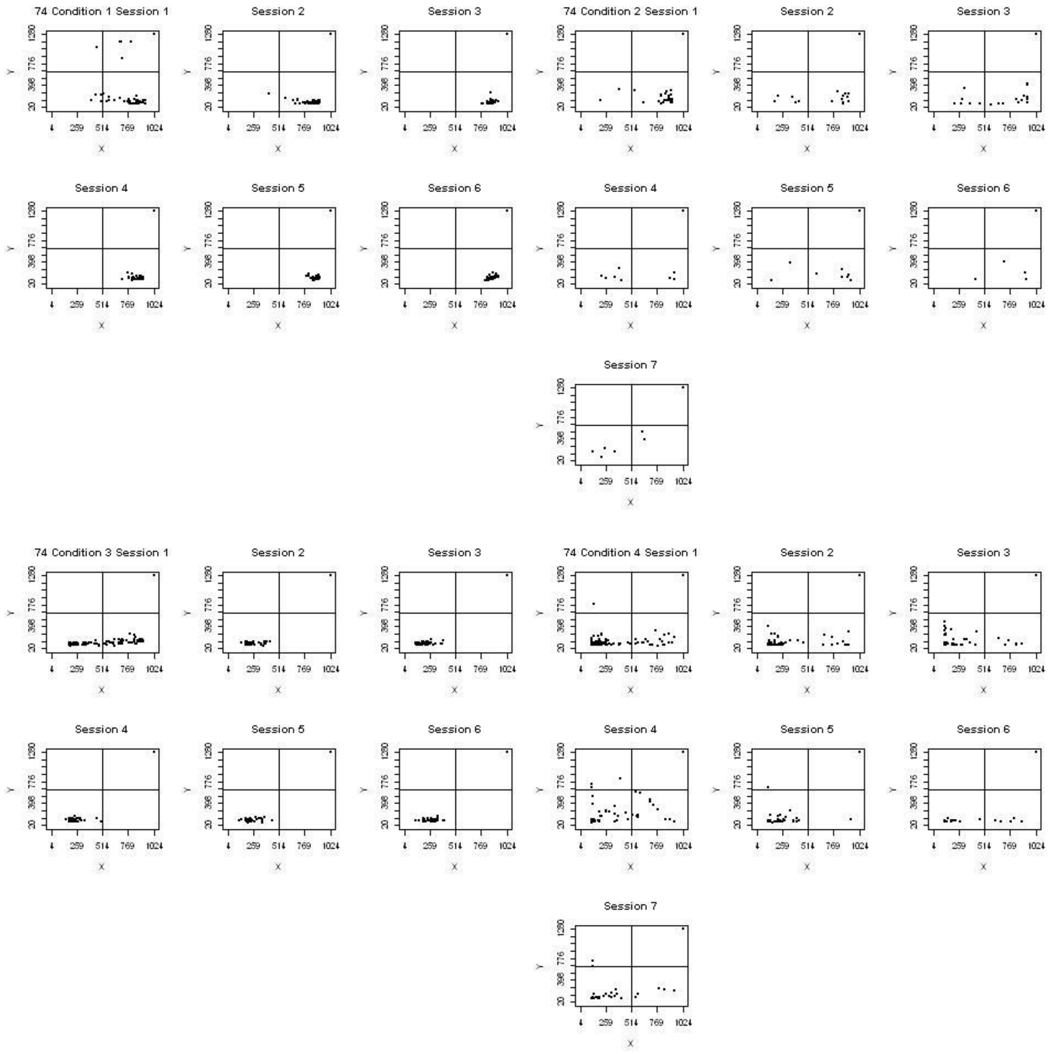


Figure 28. Hen 7.4's response locations in each session of Condition 1 to Condition 4.

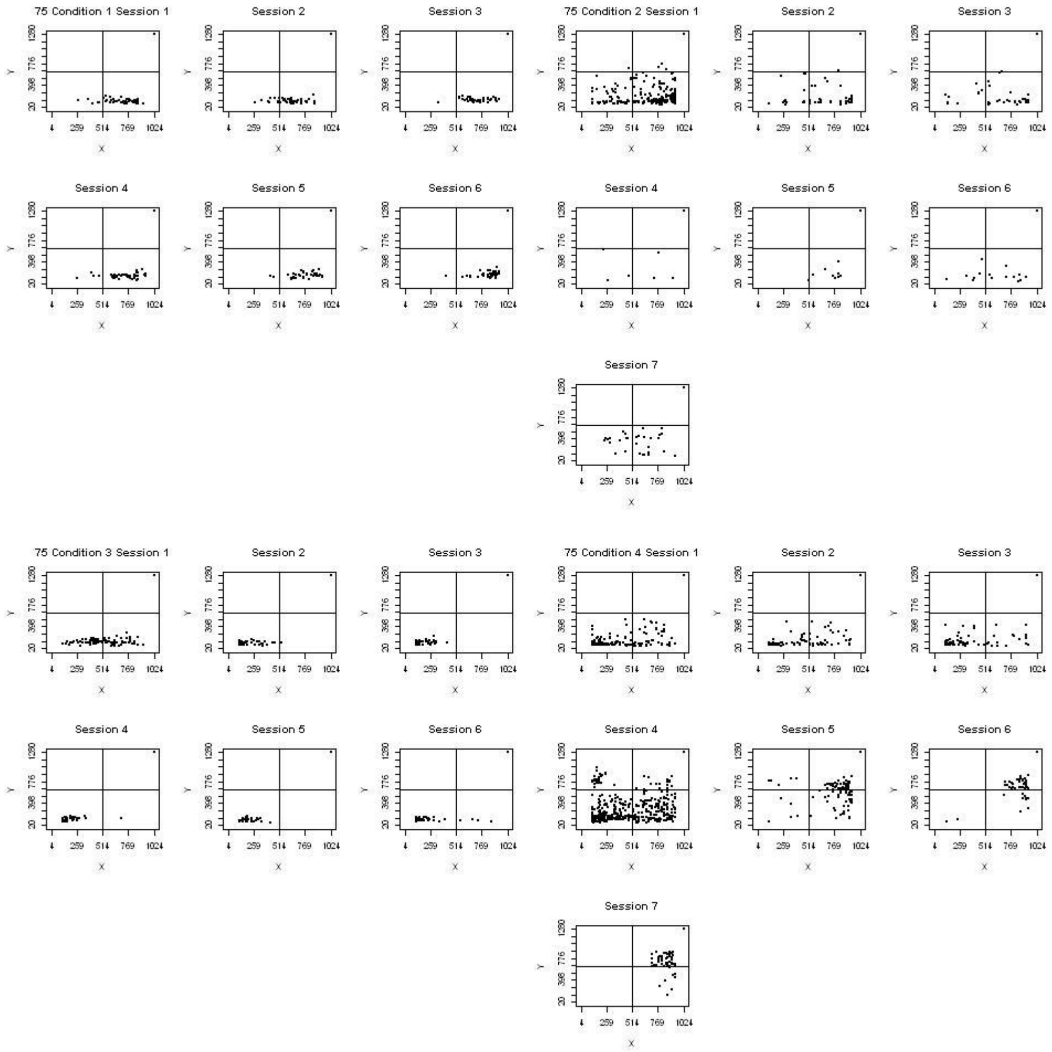


Figure 29. Hen 7.5’s response locations in each session of Condition 1 to Condition 4.

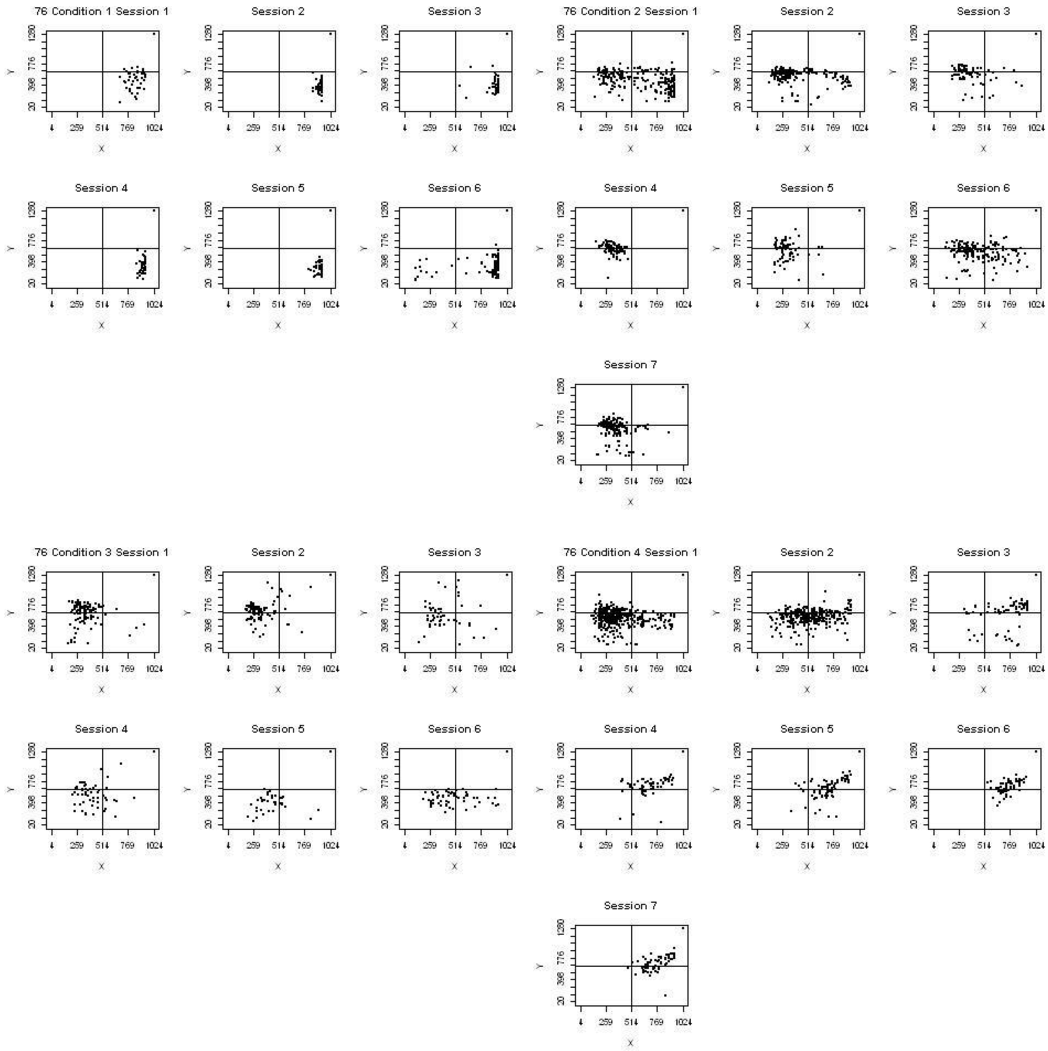


Figure 30. Hen 7.6’s response locations in each session of Condition 1 to Condition 4.

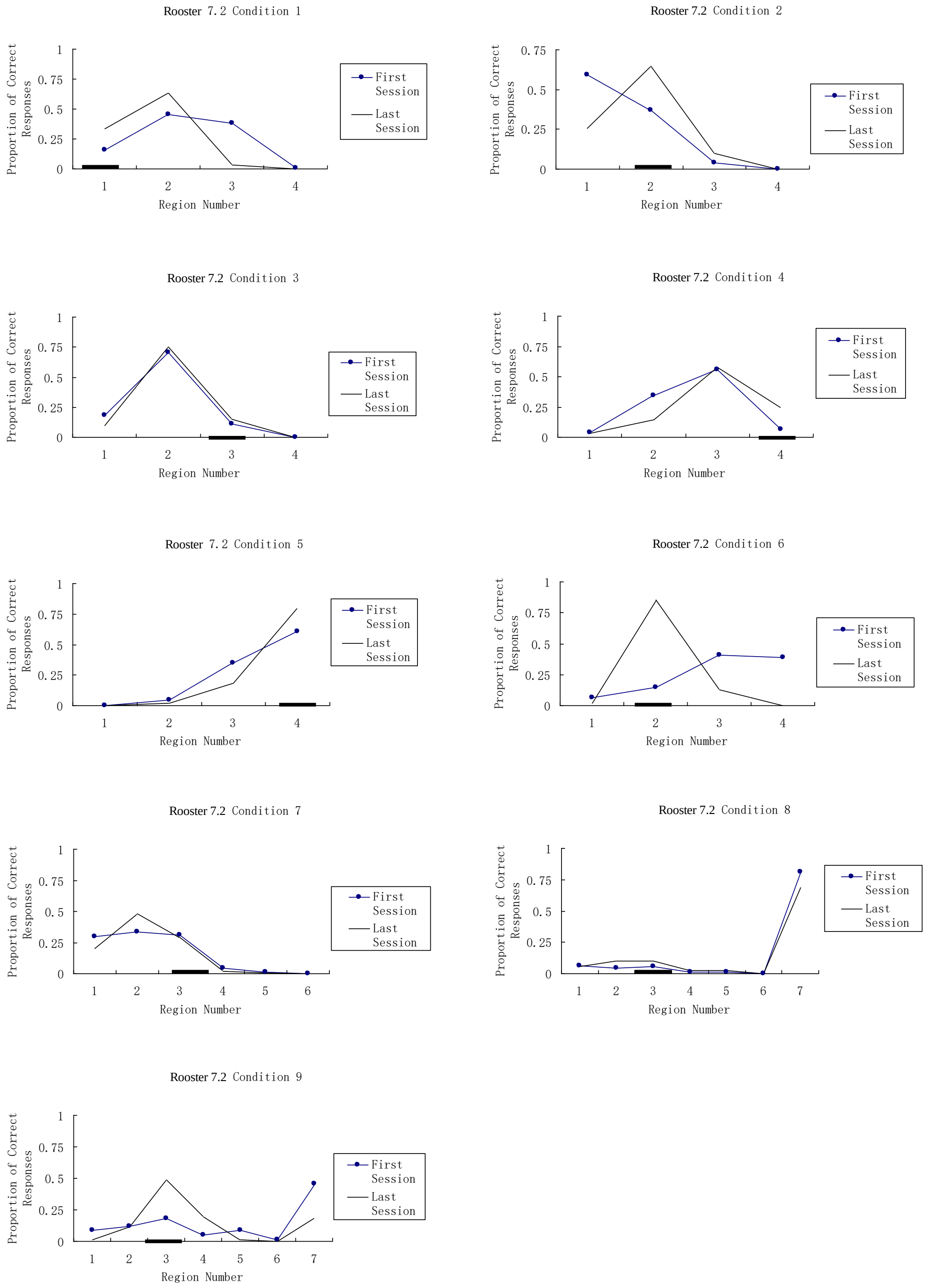


Figure 31. Roosters 7.2’s distribution of response proportion in the first and last sessions of each condition of Experiment 2. The active area is shown as a black solid line.

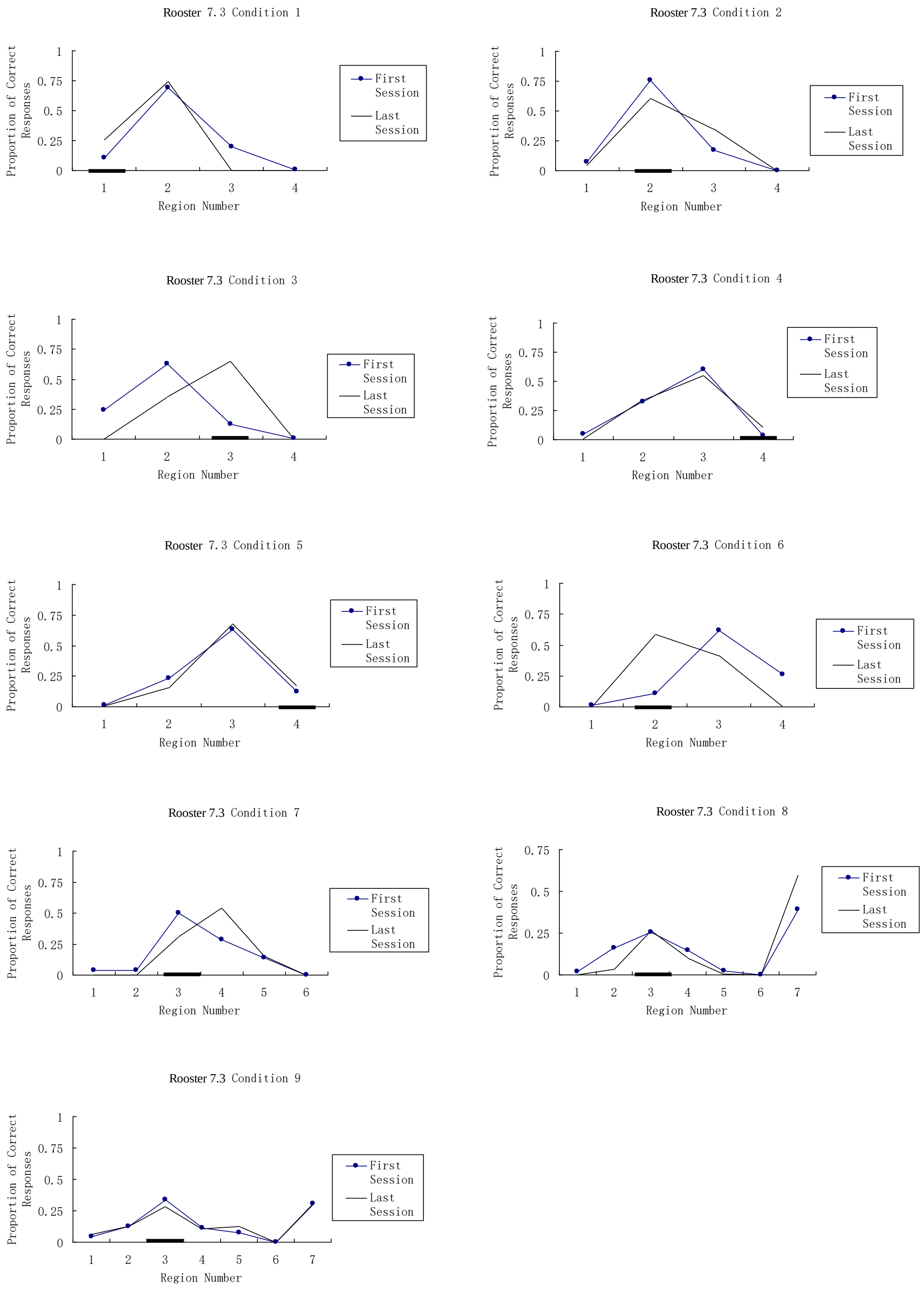


Figure 32. Roosters 7.3's distribution of response proportion in the first and last sessions of each condition of Experiment 2. The active area is shown as a black solid line.

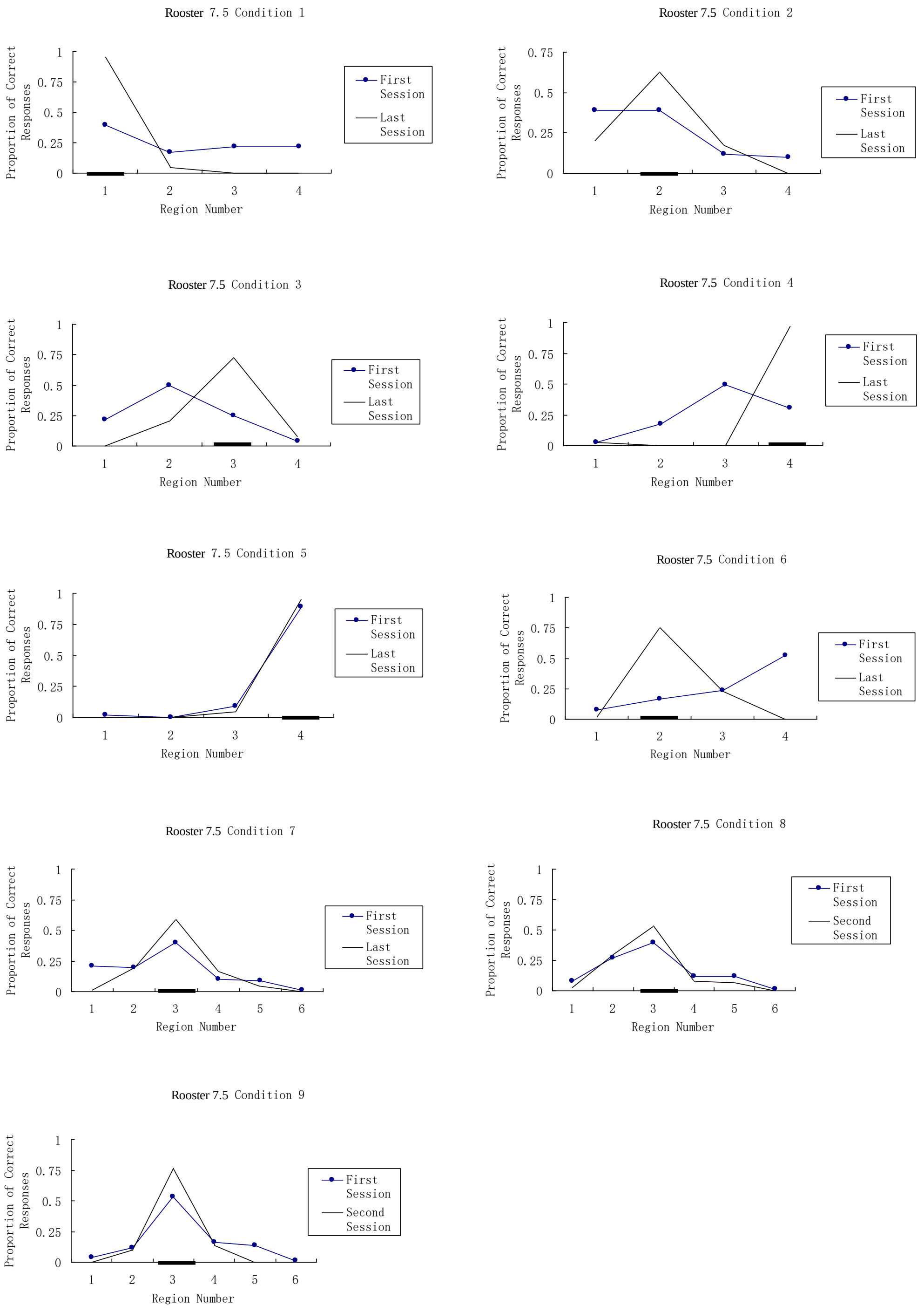
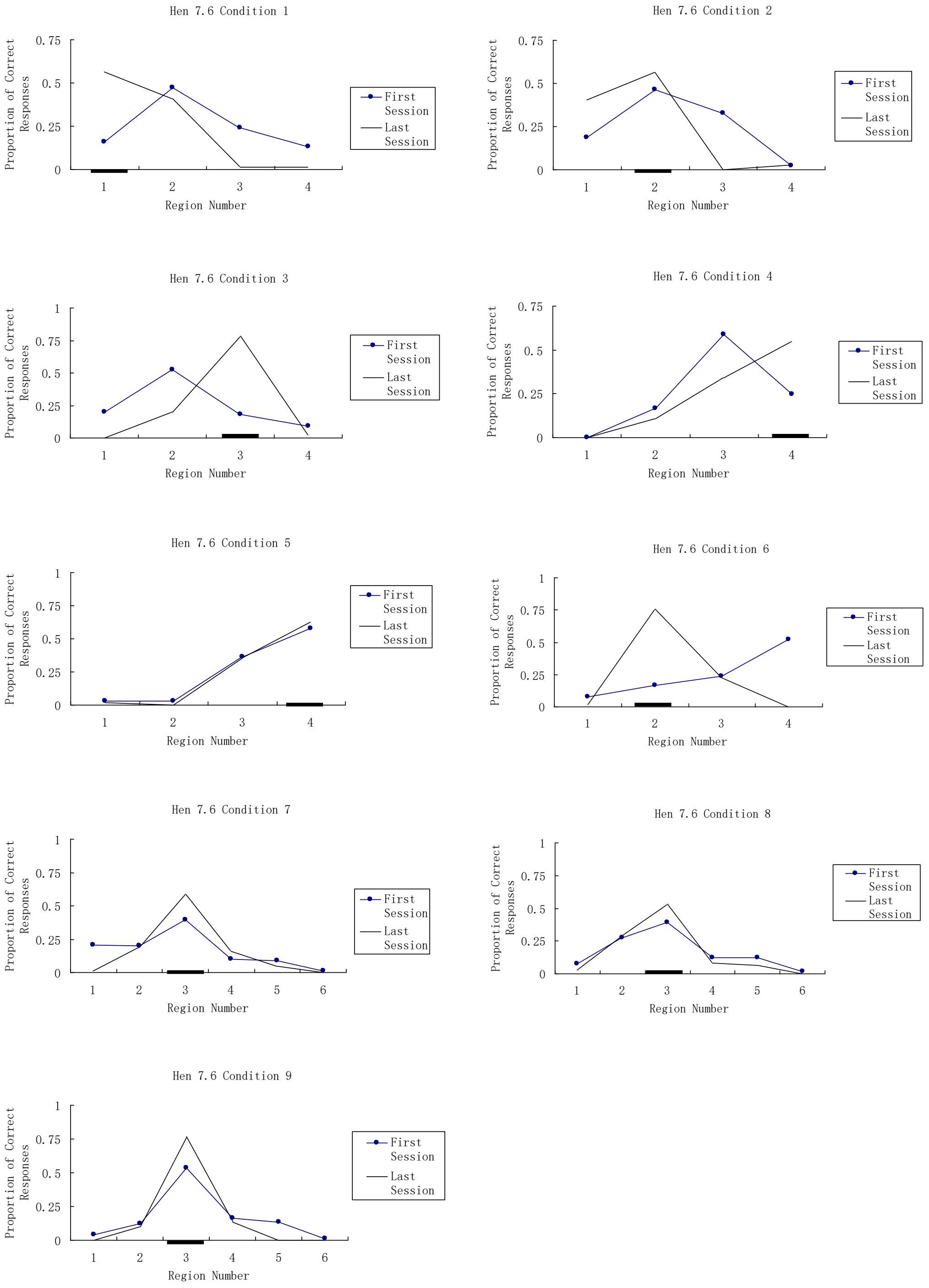


Figure 33. Hen 7.5’s distribution of response proportion in the first and last sessions of each condition of Experiment 2. The active area is shown as a black solid line.



Hen 7.6 Condition 1

Hen 7.6 Condition 2

Hen 7.6 Condition 3

Hen 7.6 Condition 4

Hen 7.6 Condition 5

Hen 7.6 Condition 6

Hen 7.6 Condition 7

Hen 7.6 Condition 8

Hen 7.6 Condition 9

Figure 34. Hen 7.6’s distribution of response proportion in the first and last sessions of each condition of Experiment 2. The active area is shown as a black solid line.

Rooster 7.1

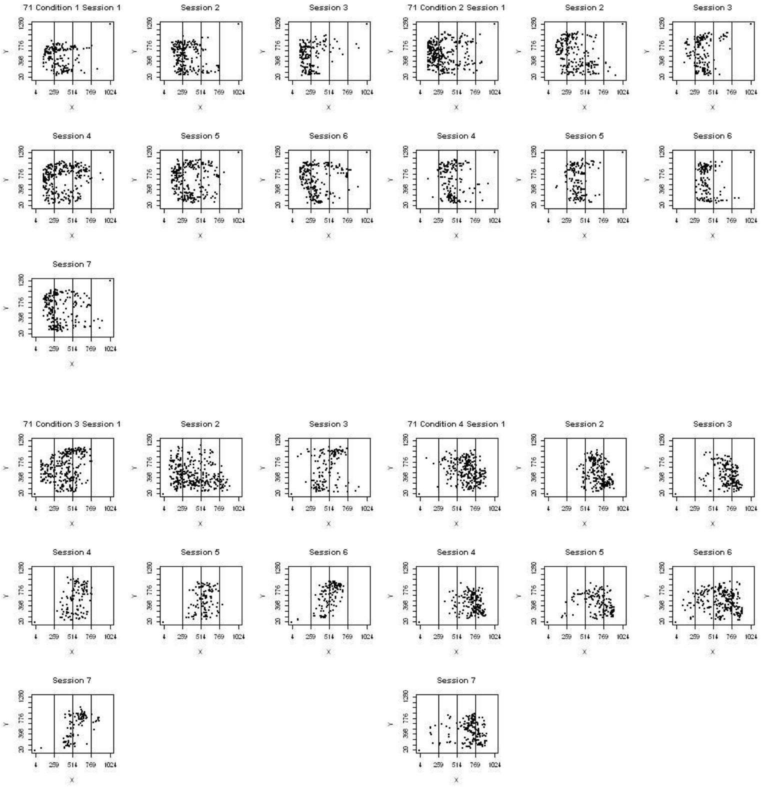


Figure 35. Rooster 7.1's response locations on the screen of all sessions of Conditions 1 to 4 during Experiment 2.

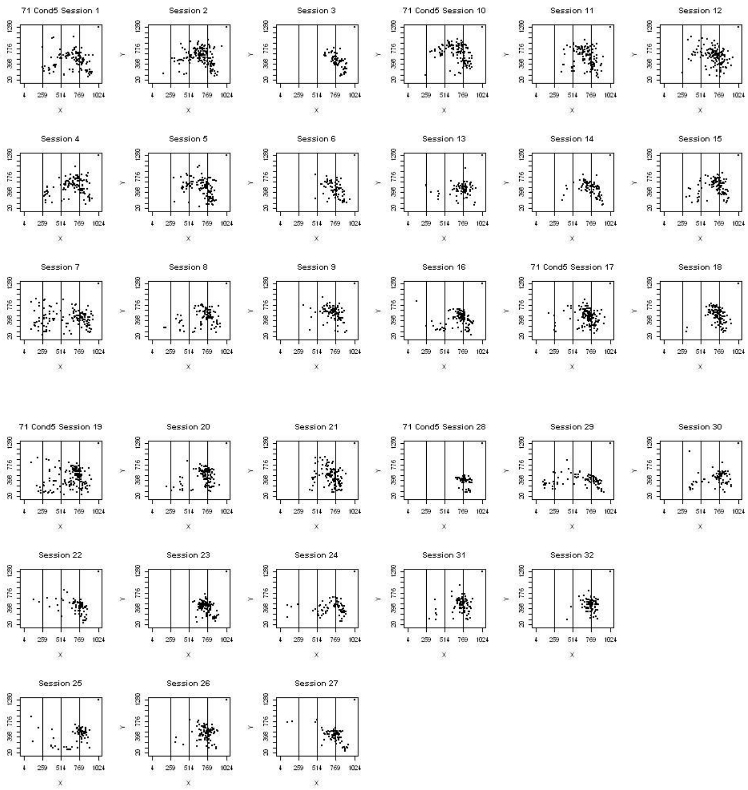

71 Cond5 Session 1
Session 2
Session 3
71 Cond5 Session 10
Session 11
Session 12
Session 4
Session 5
Session 6
Session 13
Session 14
Session 15
Session 7
Session 8
Session 9
Session 16
71 Cond5 Session 17
Session 18
71 Cond5 Session 19
Session 20
Session 21
71 Cond5 Session 28
Session 29
Session 30
Session 22
Session 23
Session 24
Session 31
Session 32
Session 25
Session 26
Session 27

Figure 36. Rooster 7.1’s response locations on the screen of all sessions of Condition 5 during Experiment 2.

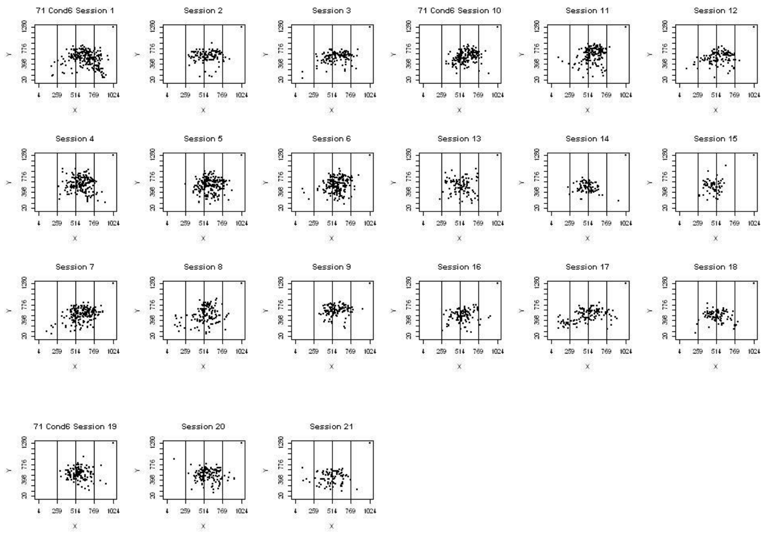


Figure 37. Rooster 7.1’s response locations on the screen of all sessions of Condition 6 during Experiment 2.

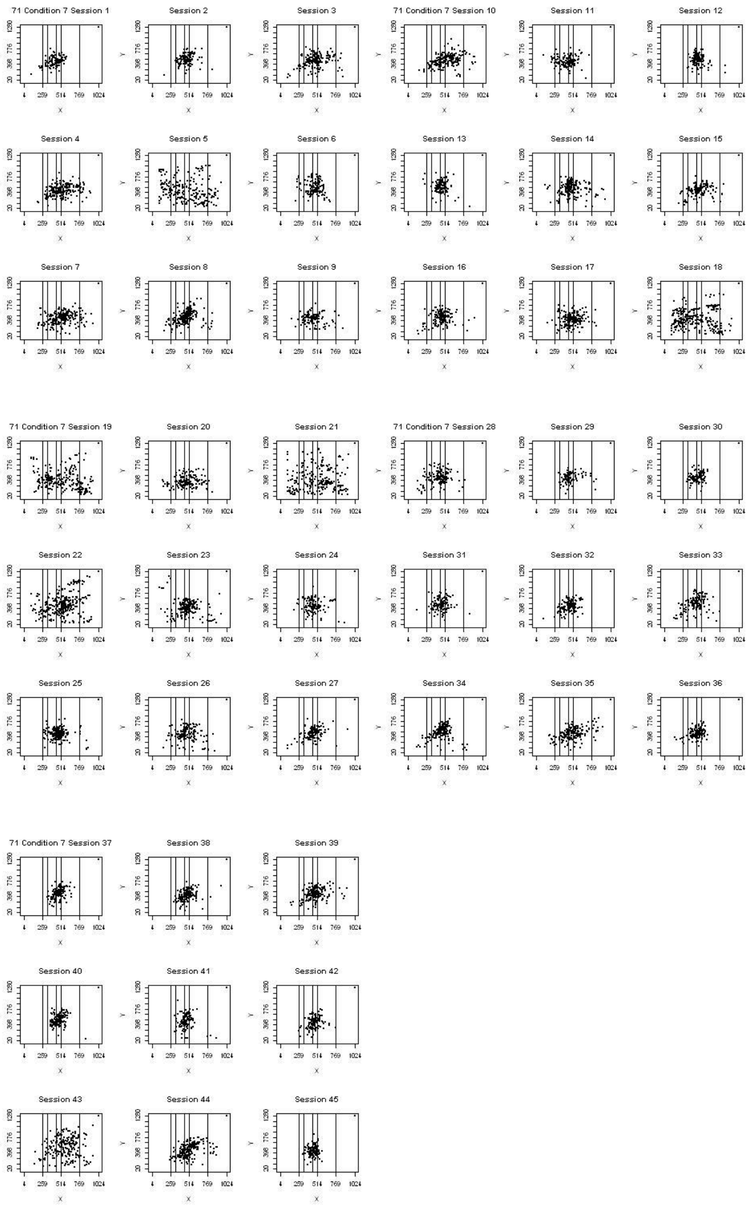


Figure 38. Rooster 7.1's response locations on the screen of all sessions of Condition 7 during Experiment 2.

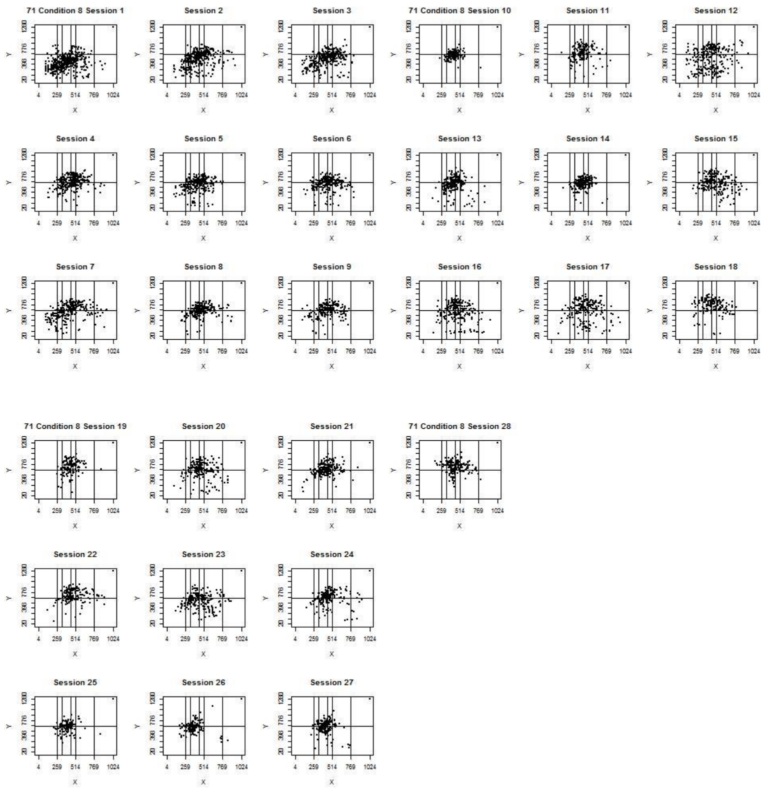


Figure 39. Rooster 7.1’s response locations on the screen of all sessions of Condition 8 during Experiment 2.

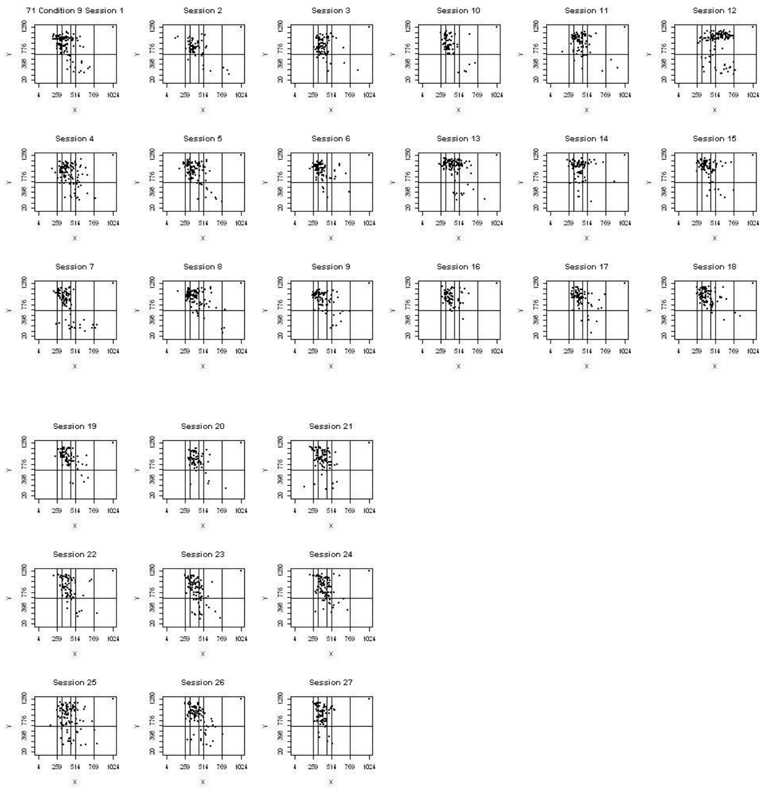


Figure 40. Rooster 7.1's response locations on the screen of all sessions of Condition 9 during Experiment 2.

Rooster 7.2

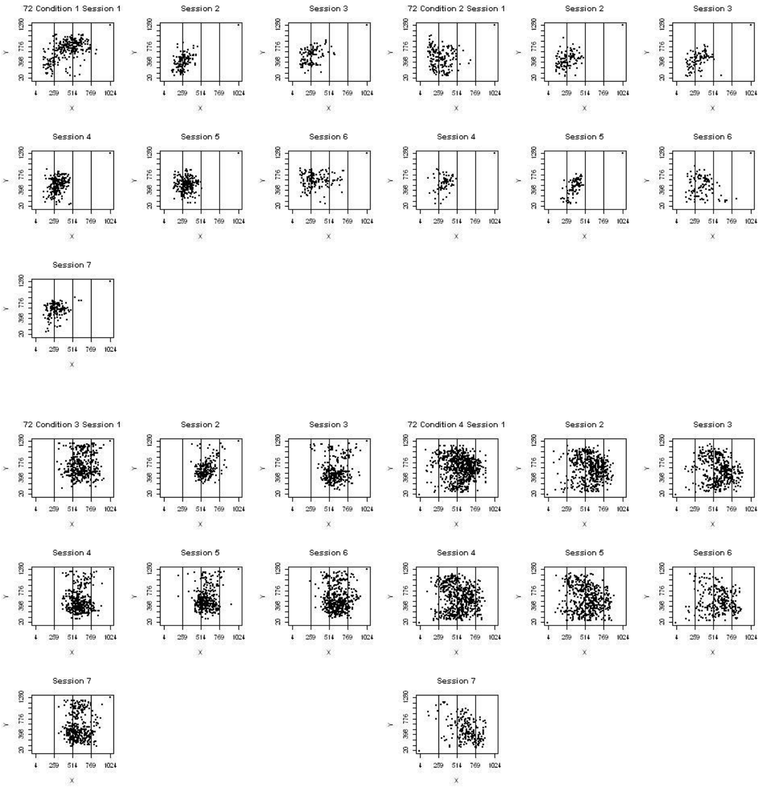


Figure 41. Rooster 7.2’s response locations on the screen of all sessions of Conditions 1 to 4 during Experiment 2.

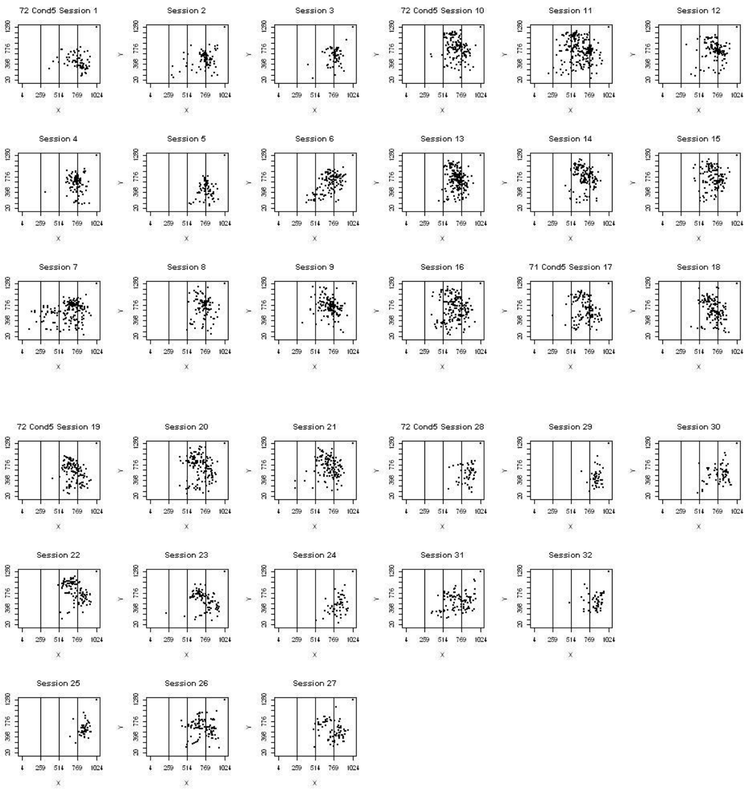

72 Cond5 Session 1
Session 2
Session 3
72 Cond5 Session 10
Session 11
Session 12
Session 4
Session 5
Session 6
Session 13
Session 14
Session 15
Session 7
Session 8
Session 9
Session 16
71 Cond5 Session 17
Session 18
72 Cond5 Session 19
Session 20
Session 21
72 Cond5 Session 28
Session 29
Session 30
Session 22
Session 23
Session 24
Session 31
Session 32
Session 25
Session 26
Session 27

Figure 42. Rooster 7.2's response locations on the screen of all sessions of Condition 5 during Experiment 2.

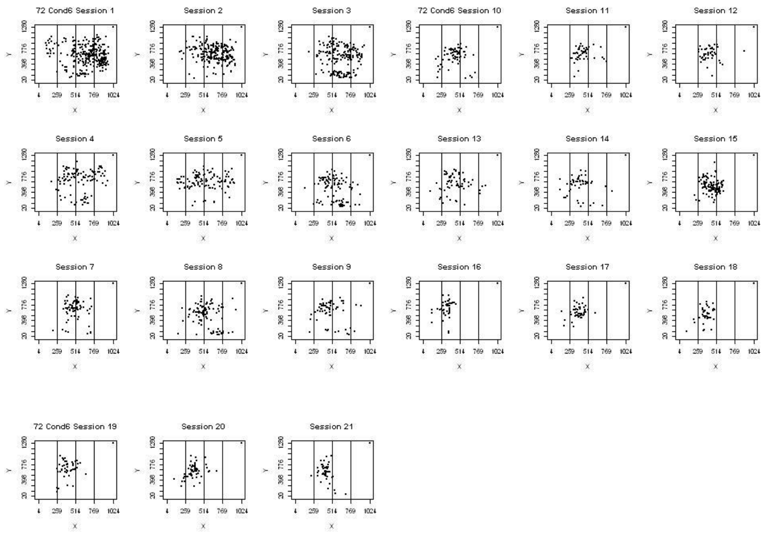


Figure 43. Rooster 7.2’s response locations on the screen of all sessions of Condition 6 during Experiment 2.

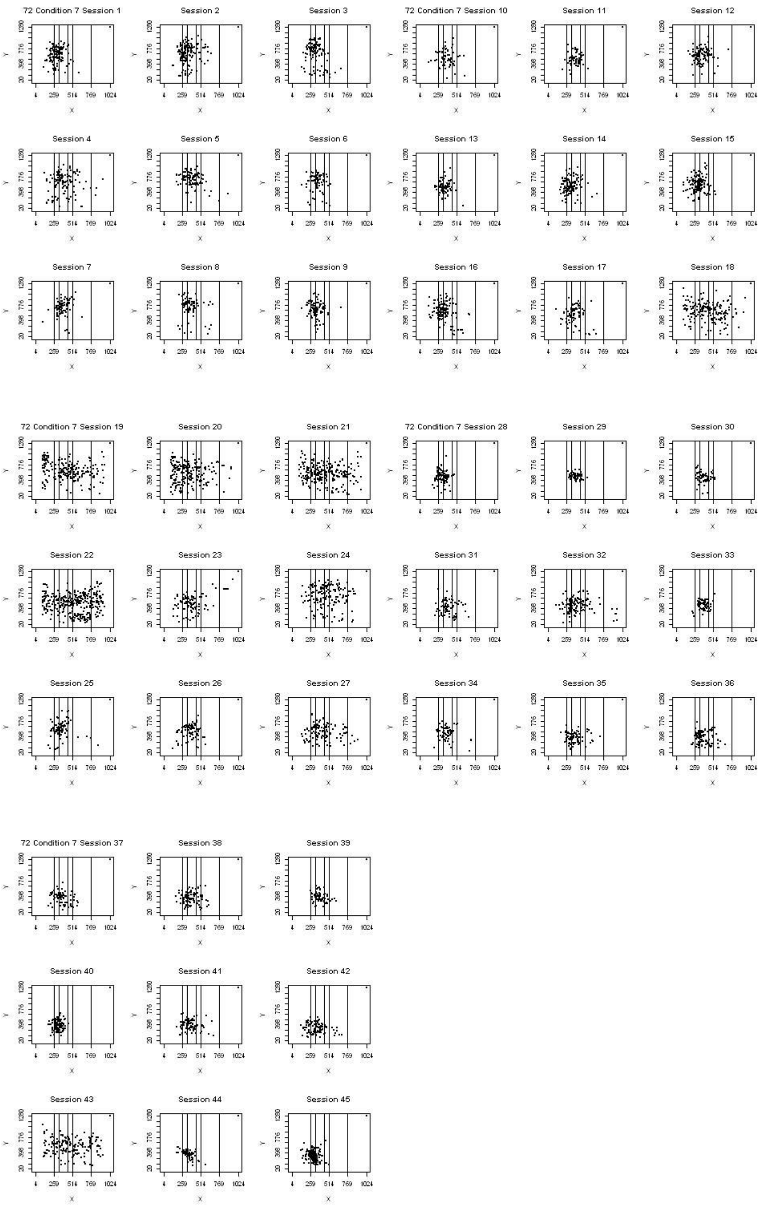


Figure 44. Rooster 7.2’s response locations on the screen of all sessions of Condition 7 during Experiment 2.

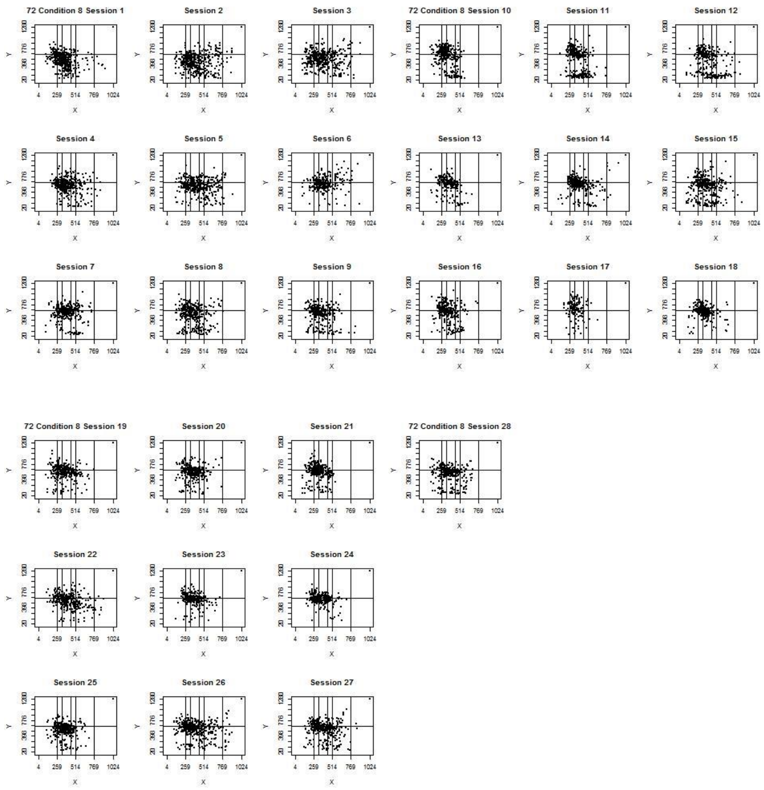


Figure 45. Rooster 7.2's response locations on the screen of all sessions of Condition 8 during Experiment 2.

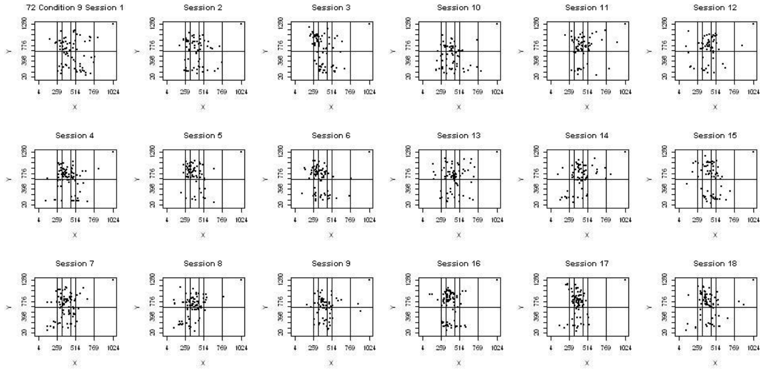


Figure 46. Rooster 7.2’s response locations on the screen of all sessions of Condition 9 during Experiment 2.

Rooster 7.3

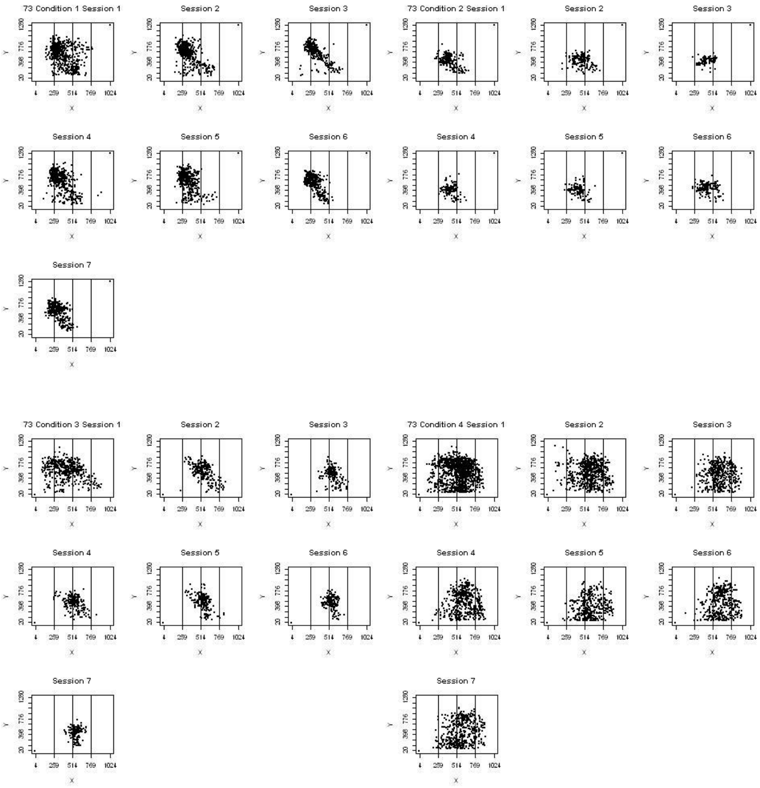


Figure 47. Rooster 7.3's response locations on the screen of all sessions of Conditions 1 to 4 during Experiment 2.

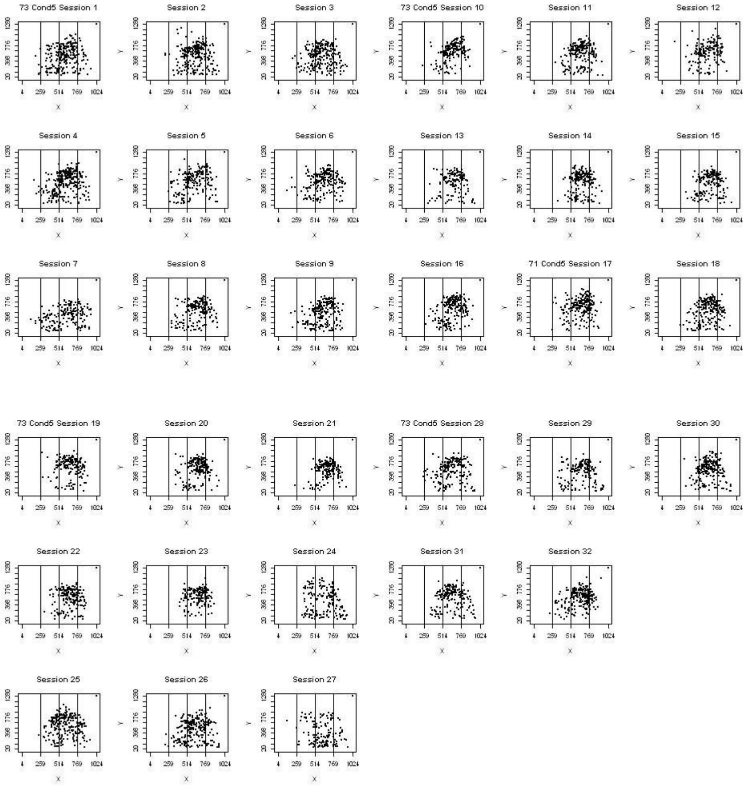


Figure 48. Rooster 7.3’s response locations on the screen of all sessions of Condition 5 during Experiment 2.

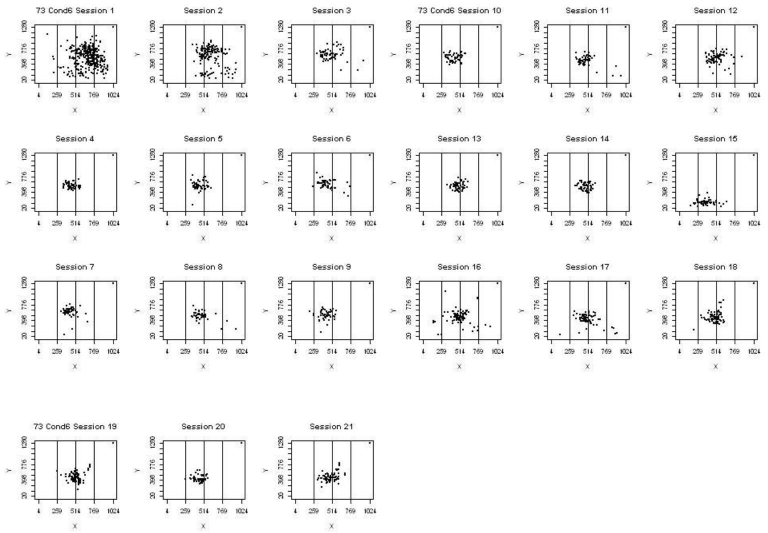


Figure 49. Rooster 7.3’s response locations on the screen of all sessions of Condition 6 during Experiment 2.

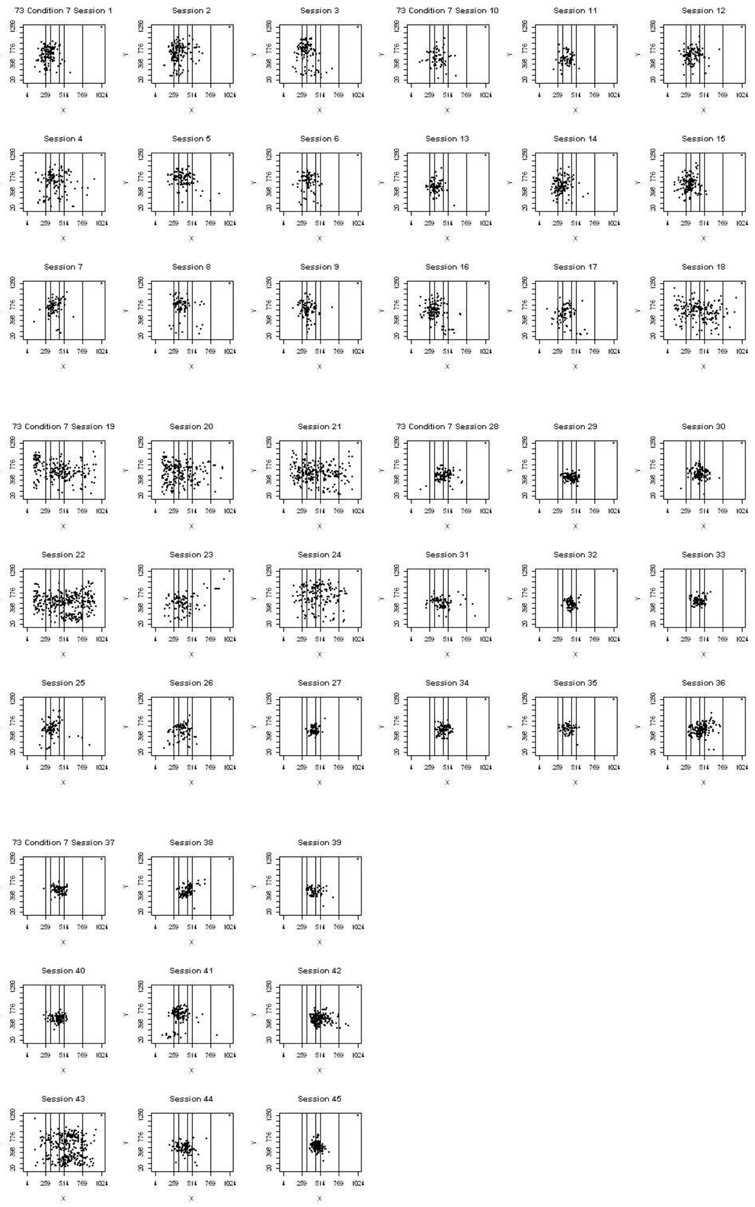


Figure 50. Rooster 7.3's response locations on the screen of all sessions of Condition 7 during Experiment 2.

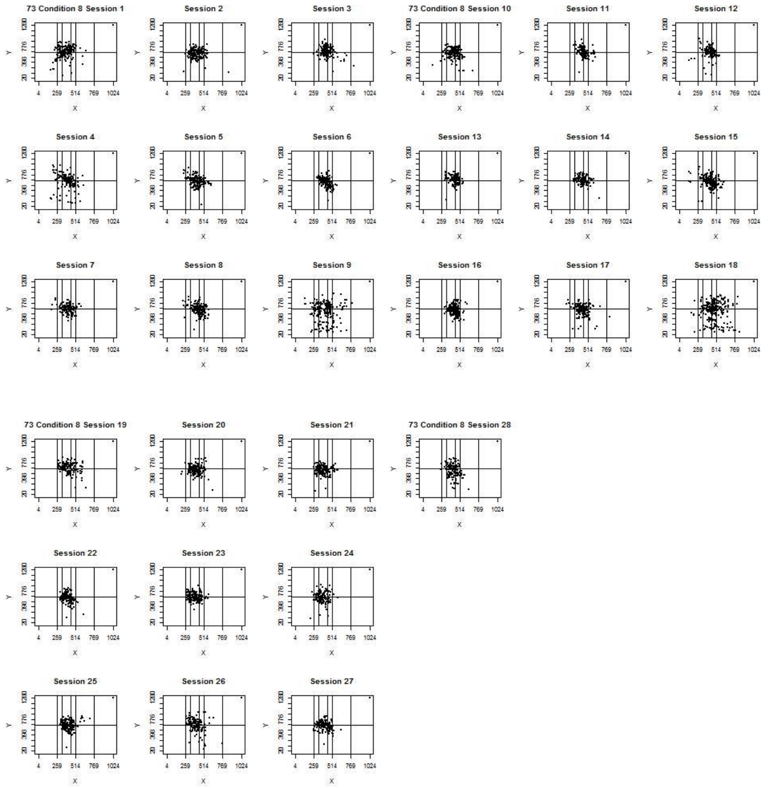


Figure 51. Rooster 7.3's response locations on the screen of all sessions of Condition 8 during Experiment 2.

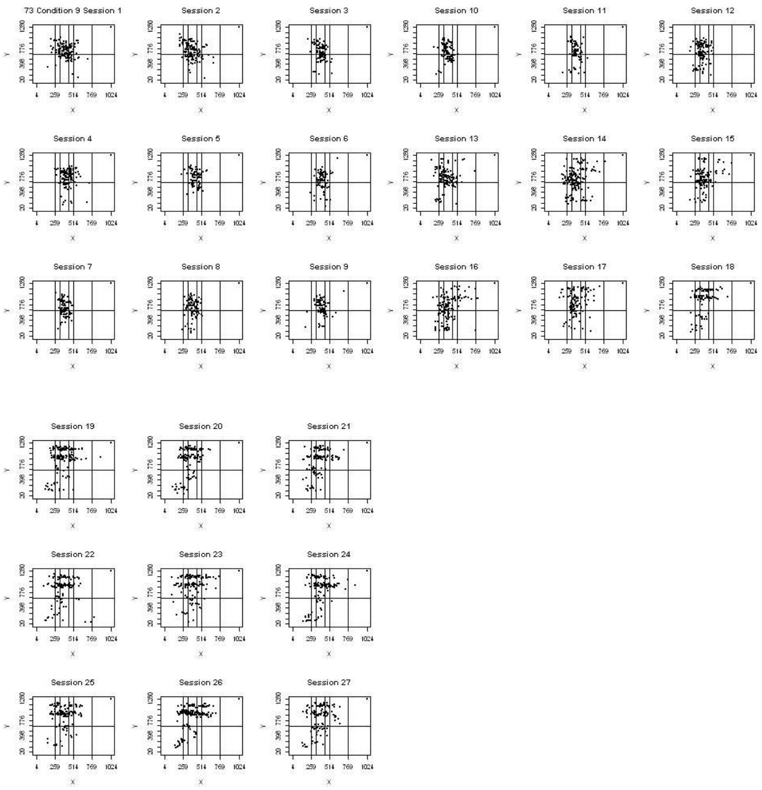


Figure 52. Rooster 7.3’s response locations on the screen of all sessions of Condition 9 during Experiment 2.

Hen 7.4

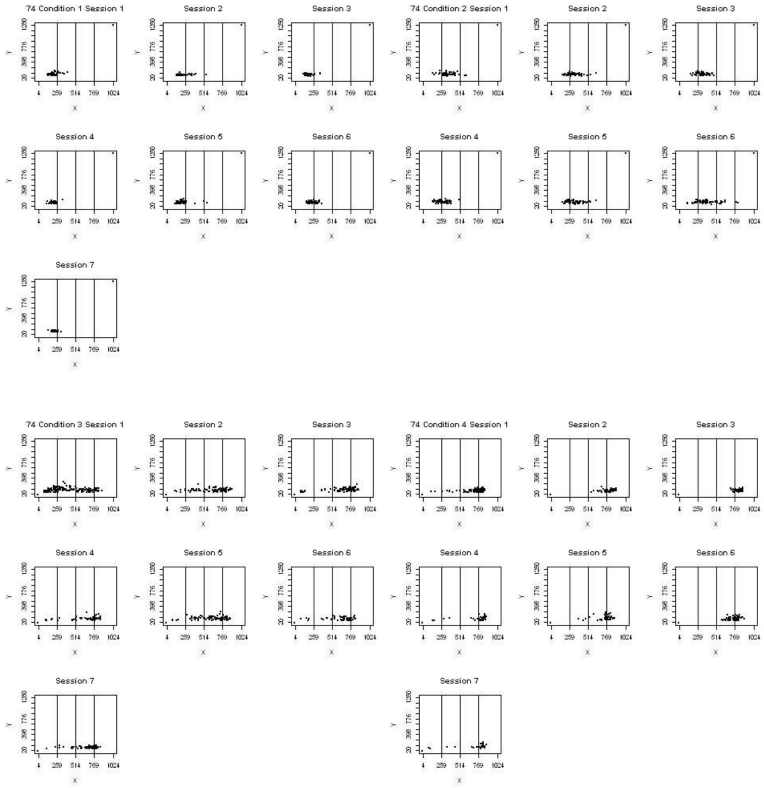


Figure 53. Hen 7.4’s response locations on the screen of all sessions of Conditions 1 to 4 during Experiment 2.

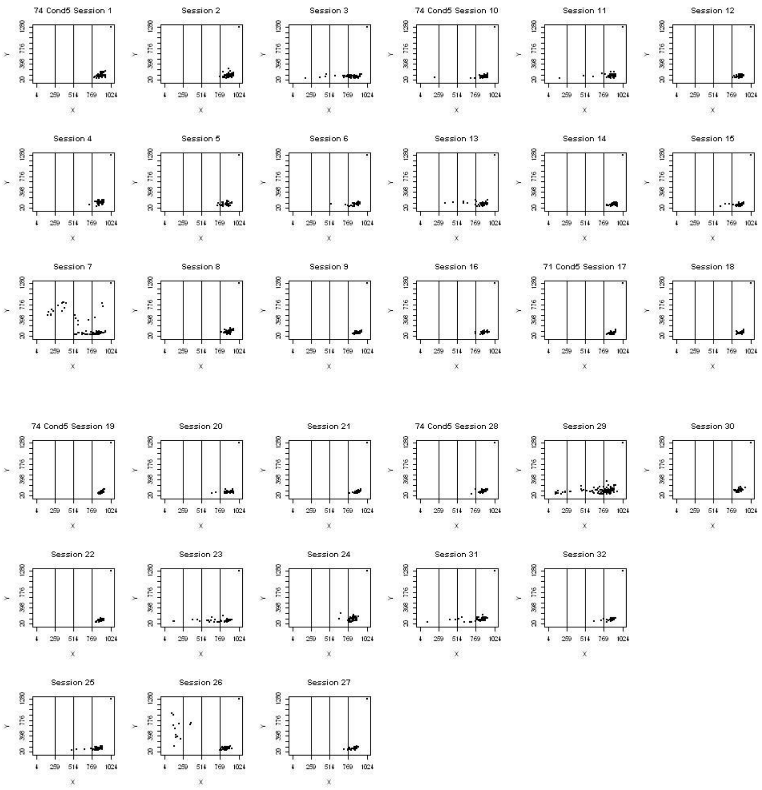


Figure 54. Hen 7.4’s response locations on the screen of all sessions of Condition 5 during Experiment 2.

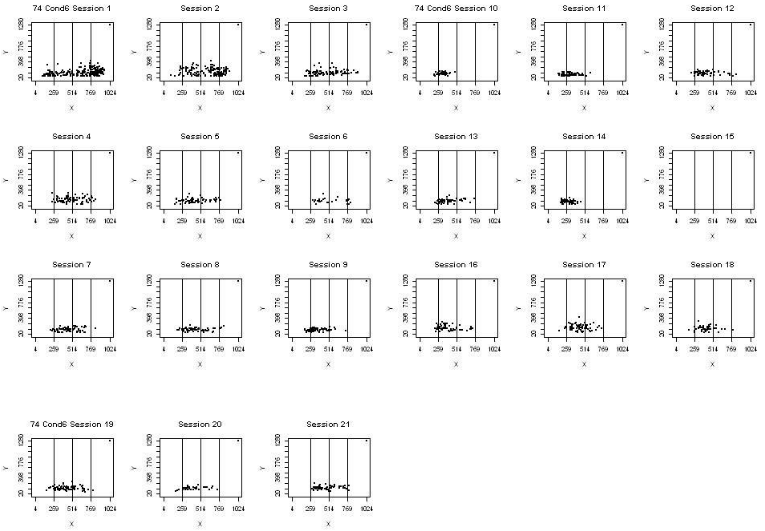


Figure 55. Hen 7.4's response locations on the screen of all sessions of Condition 6 during Experiment 2.

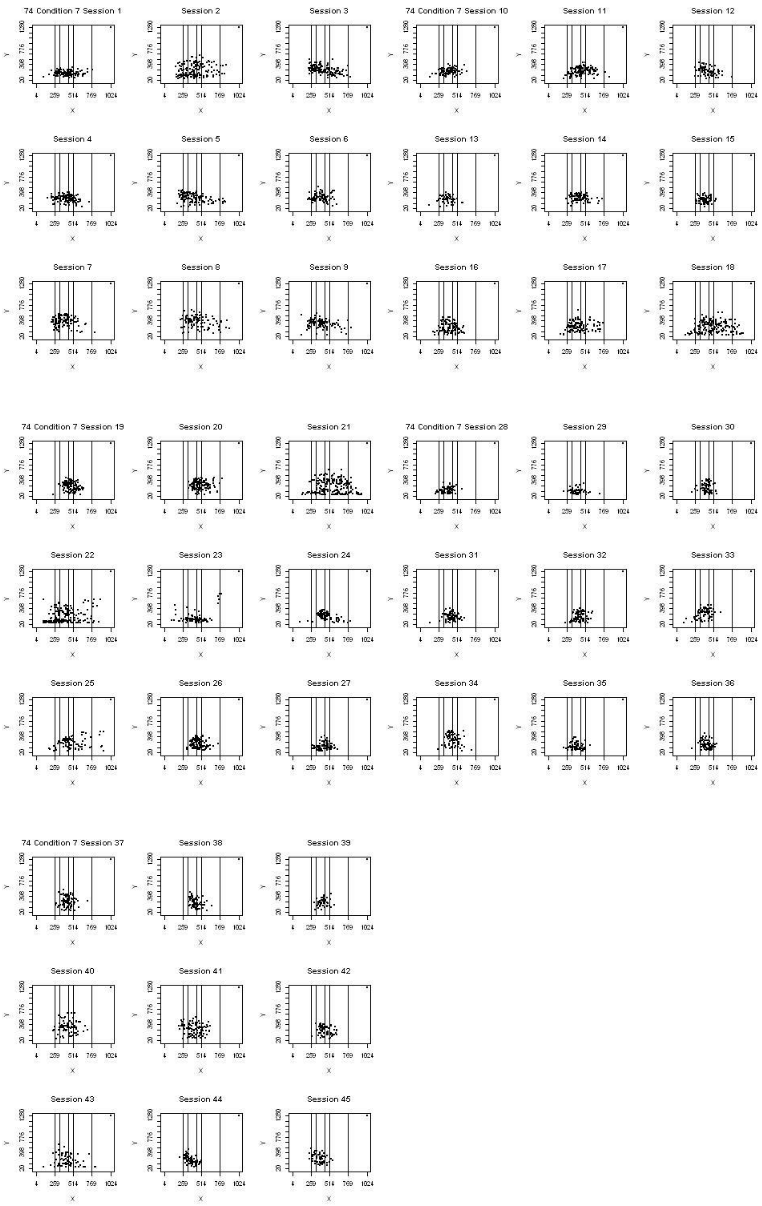


Figure 56. Hen 7.4's response locations on the screen of all sessions of Condition 7 during Experiment 2.

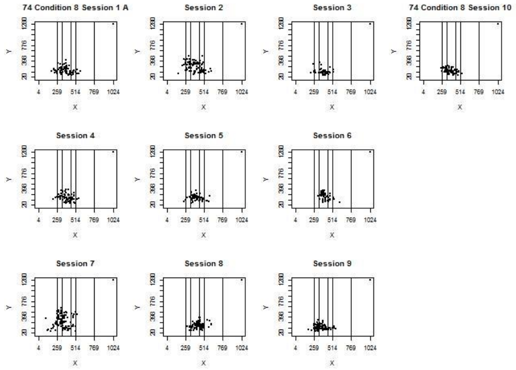


Figure 57. Hen 7.4’s response locations on the screen of all sessions of Condition 8 during Experiment 2.

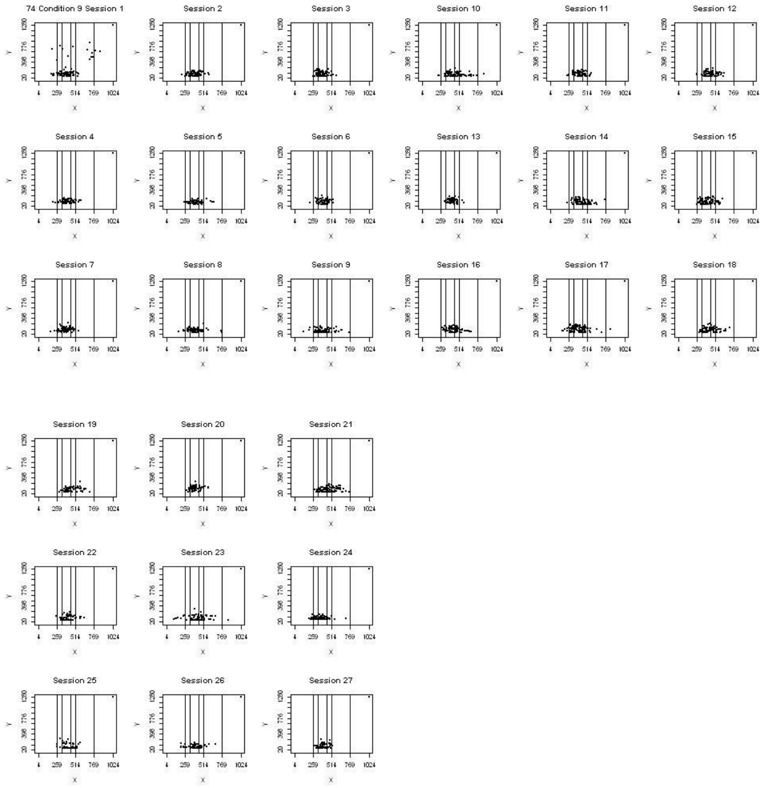


Figure 58. Hen 7.4’s response locations on the screen of all sessions of Condition 9 during Experiment 2.

Hen 7.5

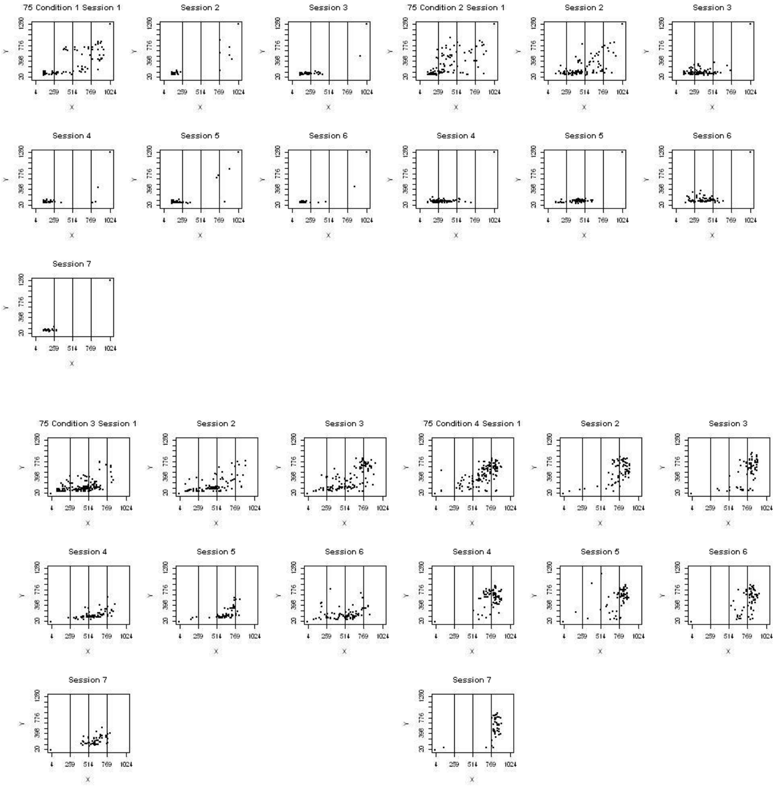


Figure 59. Hen 7.5’s response locations on the screen of all sessions of Conditions 1 to 4 during Experiment 2.

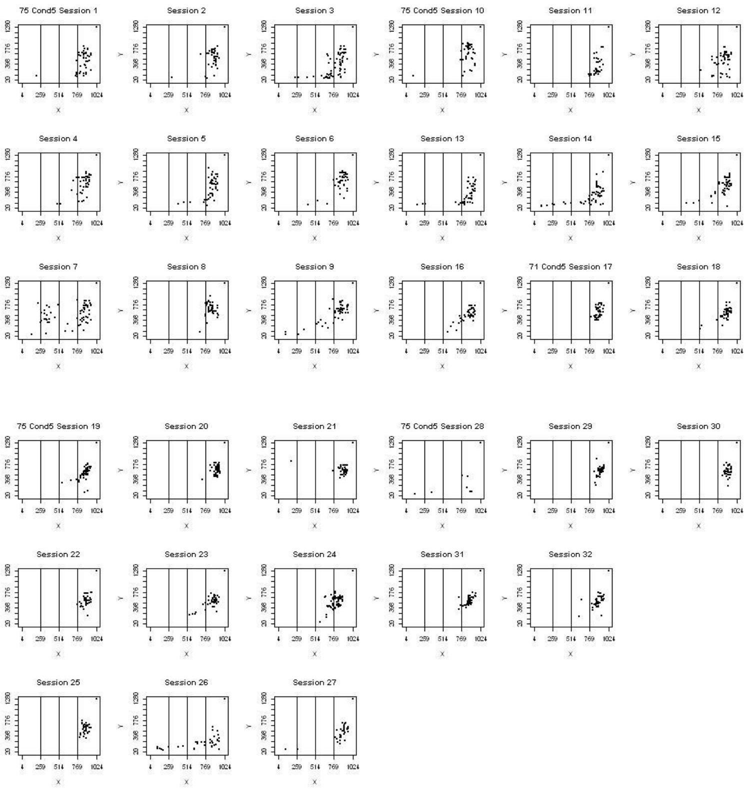


Figure 60. Hen 7.5's response locations on the screen of all sessions of Condition 5 during Experiment 2.

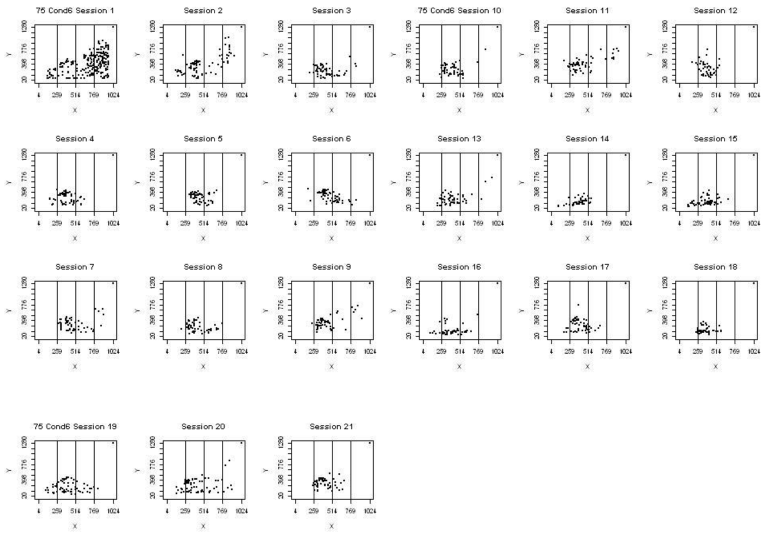


Figure 61. Hen 7.5’s response locations on the screen of all sessions of Condition 6 during Experiment 2.

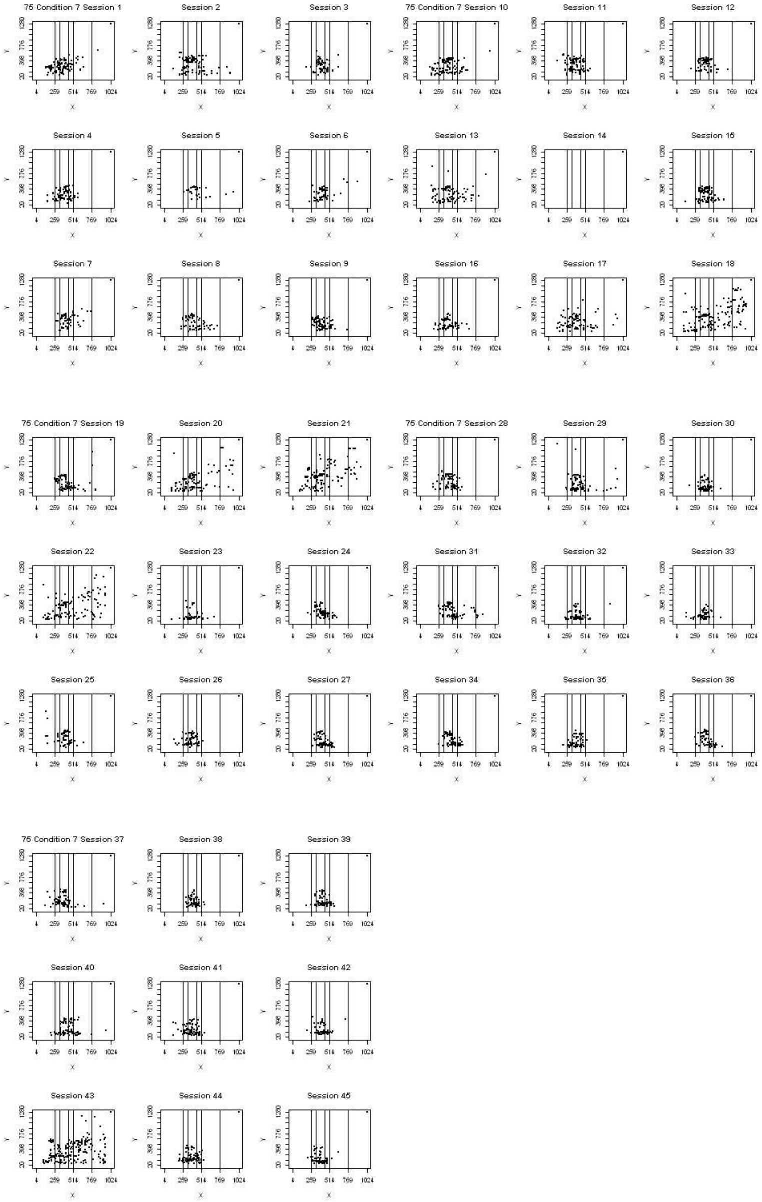
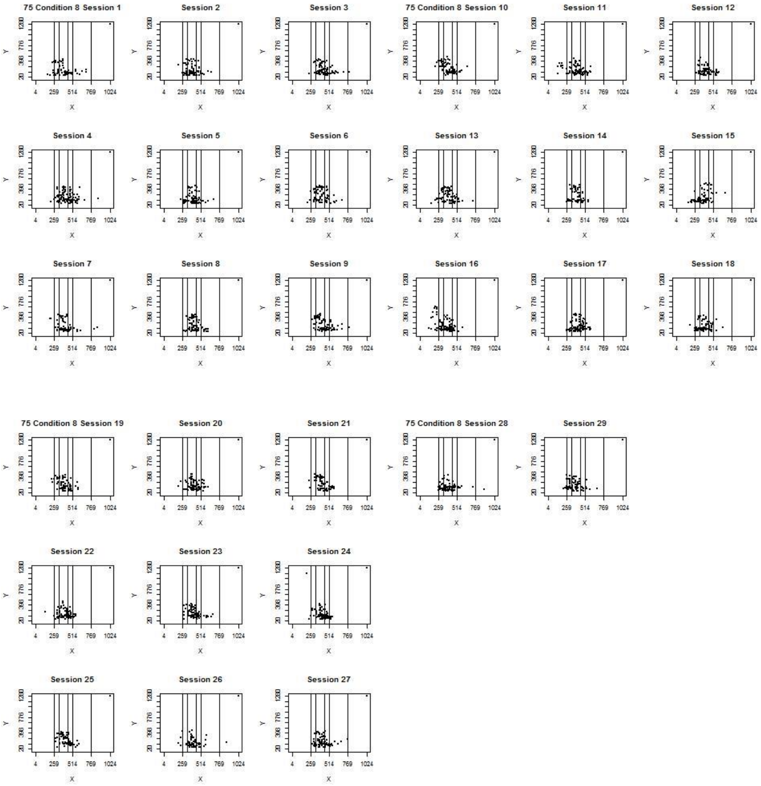


Figure 62. Hen 7.5’s response locations on the screen of all sessions of Condition 7 during Experiment 2.



75 Condition 8 Session 1
Session 2
Session 3
75 Condition 8 Session 10
Session 11
Session 12
Session 4
Session 5
Session 6
Session 13
Session 14
Session 15
Session 7
Session 8
Session 9
Session 16
Session 17
Session 18
75 Condition 8 Session 19
Session 20
Session 21
75 Condition 8 Session 28
Session 29
Session 22
Session 23
Session 24
Session 25
Session 26
Session 27

Figure 63. Hen 7.5's response locations on the screen of all sessions of Condition 8 during Experiment 2.

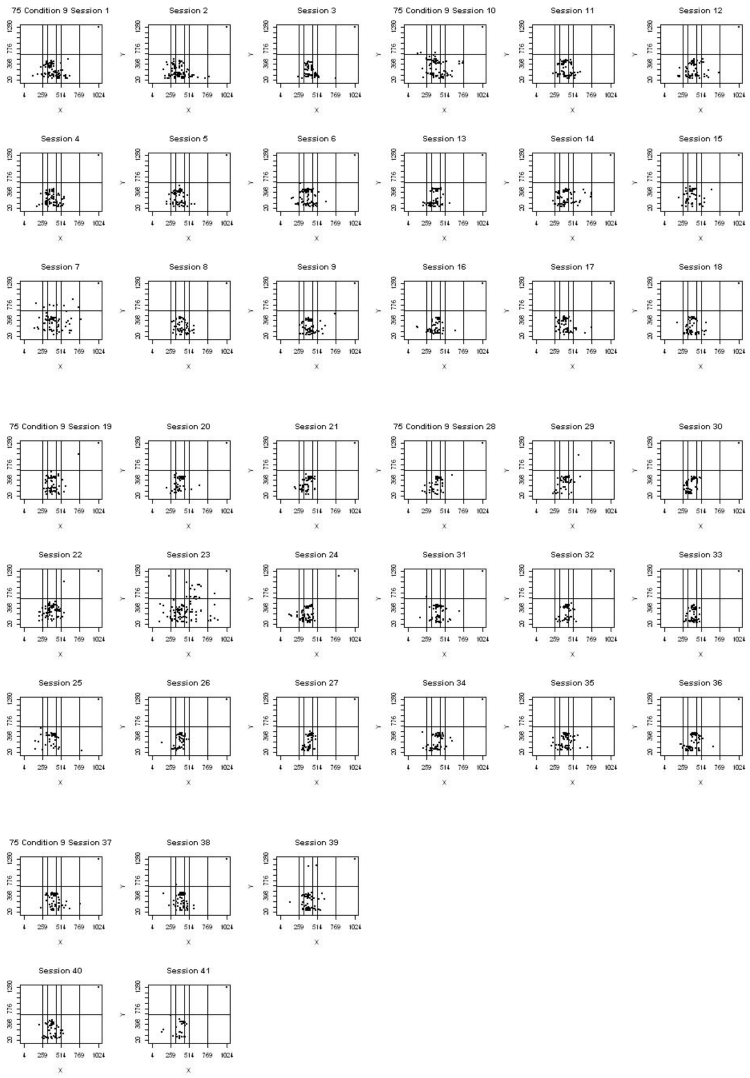


Figure 64. Hen 7.5’s response locations on the screen of all sessions of Condition 9 during Experiment 2.

Hen 7.6

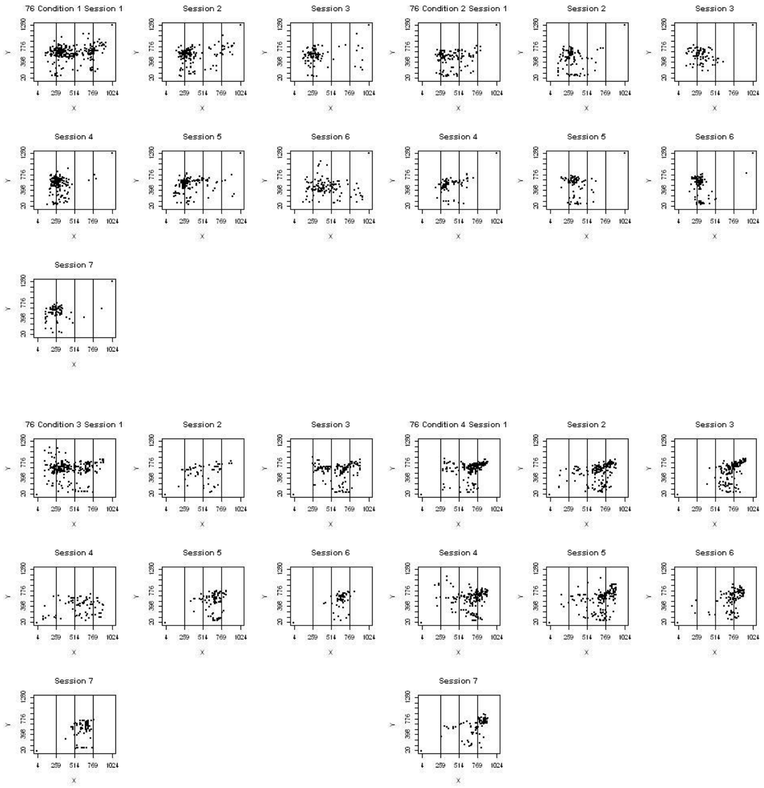


Figure 65. Hen 7.5's response locations on the screen of all sessions of Conditions 1 to 4 during Experiment 2.

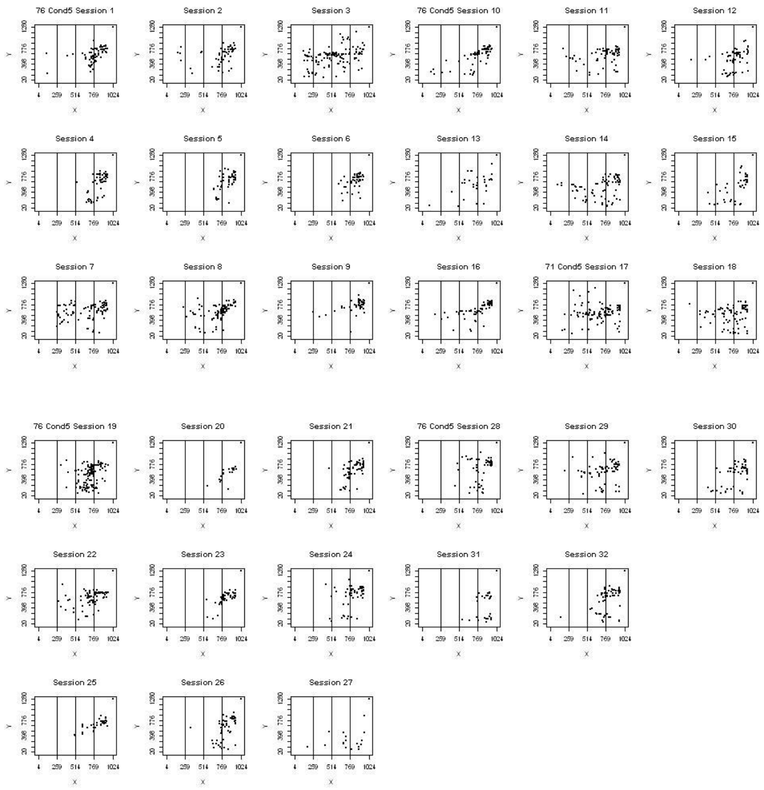


Figure 66. Hen 7.5's response locations on the screen of all sessions of Condition 5 during Experiment 2.

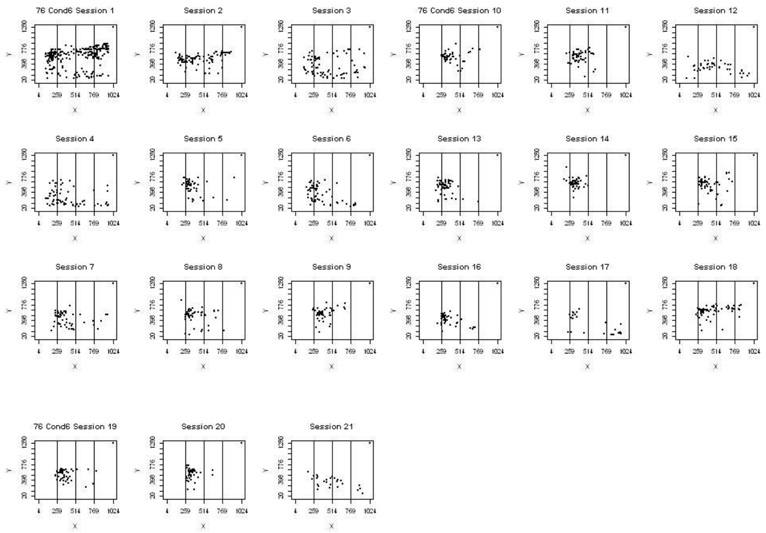


Figure 67. Hen 7.5’s response locations on the screen of all sessions of Condition 6 during Experiment 2.

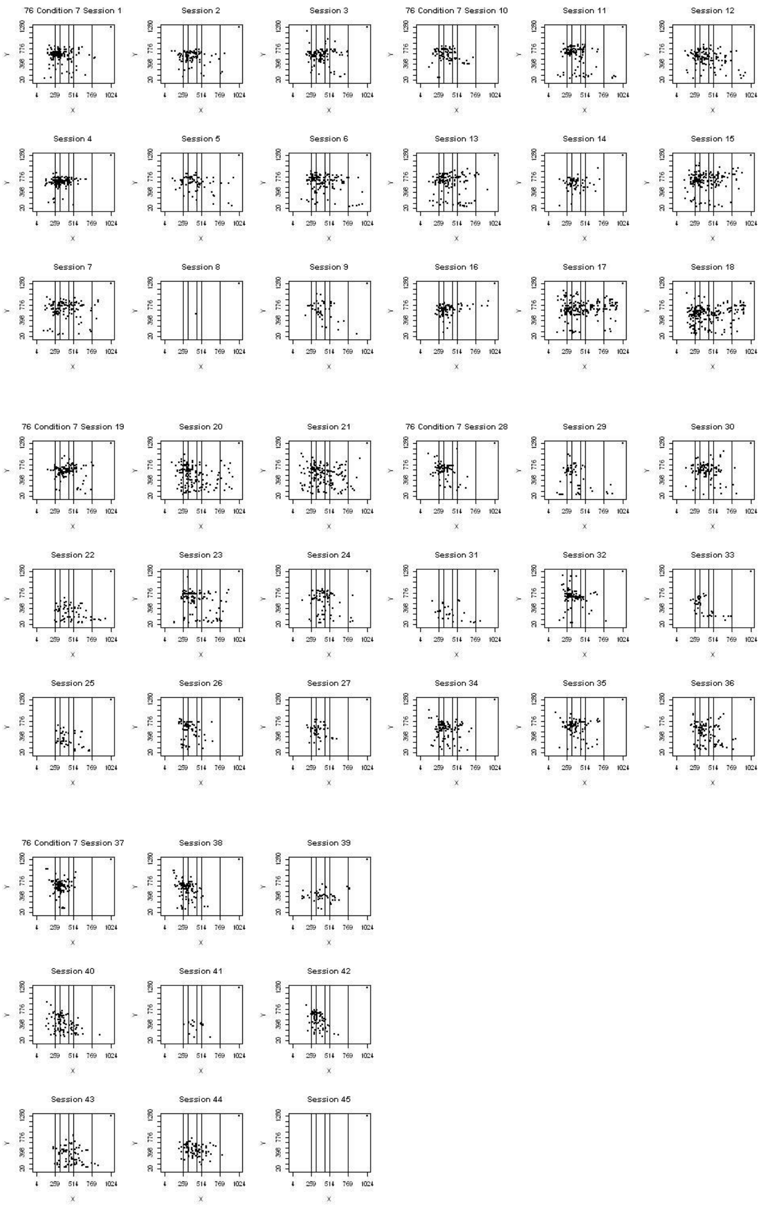


Figure 68. Hen 7.5's response locations on the screen of all sessions of Condition 7 during Experiment 2.

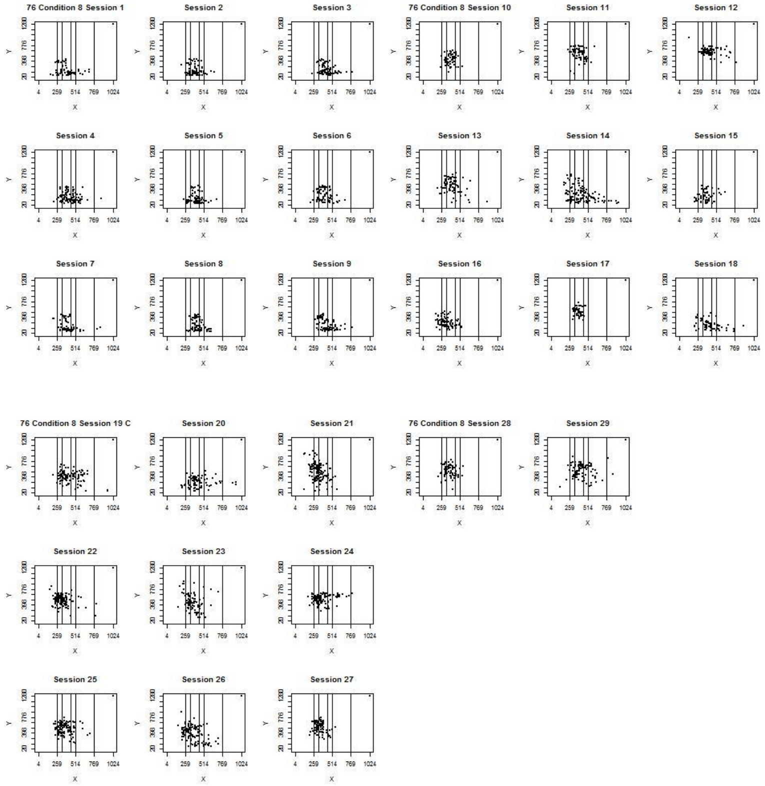


Figure 69. Hen 7.5’s response locations on the screen of all sessions of Condition 8 during Experiment 2.

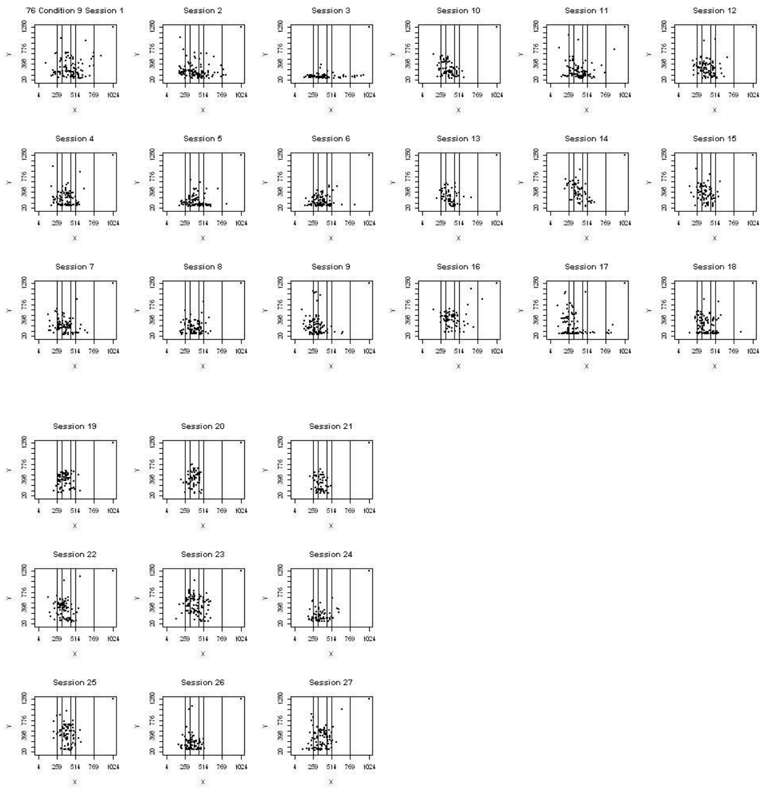


Figure 70. Hen 7.5’s response locations on the screen of all sessions of Condition 9 during Experiment 2.

Appendix B.

The CD contains the data of the current study.