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ESCAPE FROM THE PEAK PROCEDURE

A thesis

submitted in partial fulfilment
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by

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THE UNIVERSITY OF
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Abstract

The peak procedure is a timing procedure used to measure the ability of animals to time intervals. The peak procedure consists of fixed interval (FI) trials and some non-reinforced or extinction trials (EXT). Typically, responding on EXT trial increases at the usual time of reinforcement on the FI trial then decreases and resurges towards the end of the EXT trial. One short-coming of the peak procedure is that there is only one response alternative available to the animal, which might explain why, even after extensive experience, the animals still respond at high rates at times when they would never earn food reinforcers. In my experiment, I hypothesised that the reason response rates increase towards the end of EXT trials on the peak procedure is because those responses are negatively reinforced by escaping the EXT trials and resurgence maybe the result of escape from the EXT trials. This “escape” hypothesis was tested in different conditions. Results show roosters have a sense of time and by providing an alternative key to response; the birds’ performance on the peak procedure was improved.

Keywords: escape, fixed interval schedule, negative reinforcement, peak procedure, timing

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Lastly, a big thank to my roosters. I have to admit that I did not like working with them and they probably did not like working with me. I can tell because they kept pecking and scratching me. However, I could not have completed this thesis without them. Thanks again everyone.

Table of Contents

Abstract	ii
Acknowledgements	iii
List of Tables.....	vi
List of Figures	vii
Timing	2
The Concept of Internal Clock.....	3
Models of Timing.....	5
The scalar expectancy theory (SET).	5
Behavioural theory of timing (BeT).....	7
FI Schedule/ Peak Procedure	8
Escape (Negative Reinforcement).....	12
The Aims of the Study	17
Method	17
Subjects	17
Apparatus	18
Procedure.....	18
Magazine training and key-peck shaping.....	18
Fixed-interval (FI) training.	19
Peak procedure.	21
Experimental conditions.....	21
Results	22

Discussion	28
References	37

List of Tables

Table 1. The mean (M), standard deviation (SD), and Weber fractions (WF) of EXT responses for all birds, for Condition 1 to 3 with the average displayed in the bottom row	27
Table 2. The mean (M), standard deviation (SD), and Weber fractions (WF) of EXT responses for all birds, for Condition 4 and 5 with the average displayed in the bottom row	27

List of Figures

- Figure 1.* An information processing model for timing behaviour that has three processes: a clock process, a memory process, and a decision process. Reprinted from “Scalar timing in memory,” by J. Gibbon, R. M. Church, and W. H. Meck, 1984, *Annals of the New York Academy of Sciences*, 423, p. 54. Copyright 2006 by John Wiley and Sons. 6
- Figure 2.* Peak interval performance in five experiments. (A) Female Wistar rats under various 5-HT receptor agonist and antagonist treatments. (B) PVG rats under various doses of d-amphetamine. (C) Pigeons with hippocampal lesion and sham control. (D) Starlings trained in two fixed interval (FI) schedules of reinforcement. (E) Pigeons trained in two FI schedules of reinforcement. Reprinted from “Temporal generalization accounts for response resurgence in the peak procedure,” by F. Sanabria, and P. R. Killeen, 2007, *Behavioural Processes*, 74(2), p. 127. Copyright 2006 by Elsevier B. V. 11
- Figure 3.* Photographs of the experimental chamber and the two response keys. 20
- Figure 4.* Proportion of the EXT pecks as a function of time in seconds across the session, for all birds, and for the total across birds, in the baseline conditions (FI 40 s/EXT 120 s) and Condition 2 (FI 40 s/EXT 120 s and Escape). The dash line indicates time of reinforcement under the FI trials. 25
- Figure 5.* Proportion of EXT pecks as a function of time in seconds across the session, for all birds, and for the total across birds, in the baseline conditions (FI 40 s/EXT 120 s) and Condition 5 (FI 40 s/EXT 120 s and VI60 s). The dash line indicates time of reinforcement under the FI trials. 26

Sensitivity to time is very important in our everyday life: we need to get to appointments, meet deadlines, pick up children, and cook chicken longer than we would cook steak. Imagine what would happen if we turned up late for a job interview or left a cake in an oven for longer than the required time. For animals, the ability to time is also crucial to survive in the natural environment. Evidence from casual observations, field, and laboratory studies suggests that many aspects of animal behaviour reflect sensitivity to time. It has been reported that bees visited a breakfast table every morning at the same time for marmalade (Selsam & Kaufmann, 1967); oystercatchers visited a mussel bed at the same time every day (Daan & Koene, 1981); and each day garden warblers visited the correct room at the correct time to get food (Biebach, Gordijin, & Krebs, 1989). According to Roberts (1983) a wide range of animals have the ability to discriminate time and the accuracy of discrimination does not vary substantially. Humans can tell time accurately because we have access to external time keepers such as watches and clocks, but how do animals tell time?

It has been suggested that animals have some sort of timing mechanism that is similar to a clock that humans use. This timing mechanism is known as an internal clock (Zeiler, 1998). The concept of an internal clock is worth studying because it helps organise research, it stimulates interesting research questions about animal timing such as how do animals develop sensitivity to time and it may be a physiological reality (Domjan, 1998; & Zeiler, 1998). A considerable amount of research has been conducted to try to understand the psychological processes responsible for timing in animals (e.g., Kim, 2002; Lockhart, 2011; Meck & Church, 1984; Roberts, 1981; & Roberts, Cheng, & Cohen, 1989).

In the introduction, I will discuss timing in general, review the concept of the internal clock, compare different models of timing, and discuss Fixed-Interval (FI) schedules, the peak procedure, and escape behaviour (negative reinforcement).

Timing

According to Roberts (1983) the word “timing” has no exact meaning. In general, it refers to a change in responses with time changes. For example, when a school’s bell ring in the morning, all children go inside the classroom; but when the same bell rings again in the afternoon, the children walk out of the classroom. Furthermore, the motivating event such as normal school bell versus fire alarm bell changes the function relating response (e.g., walking versus running).

One of the first and most significant psychological discoveries in relation to time-dependent behaviour in animals was Pavlovian conditioning or the inhibition of delay. In one of many examples, Pavlov (1960) blew a whistle as conditioned stimuli (CS), and then waited 3 min before dropping dilute acid, the unconditioned stimuli (US), in a dog’s mouth. Pavlov found no saliva in the first min; five drops the second min, then nine drops in the third min. The temporal relationship between the CS and US is critically important in Pavlovian conditioning. Often, the occurrence of one event signals the occurrence of another event. This is how humans and animals adjust their behaviour in advance to prepare for what is to come. For example, the absence of the CS of the familiar environment for drug-taking prevents their bodies preparing for the arrival of the drug and the usual dose of drug is therefore too much (Gutierrez-Cebollada, de la Torre, Ortuno, Garces, & Cami, 1994).

The introduction of interval schedules of reinforcement, especially fixed intervals, provides a way to observe timing in animals (Roberts, 1983). Under

interval schedules, reinforcement depends on the passage of time. For example, when reinforcement is arranged on a Fixed-Interval 30 s (FI 30 s) schedule, the first response after 30 s is reinforced. After several sessions of training, animals will be more active towards the end of the 30 s trial (e.g., peck at the lit key more often) and less active in the beginning of the trial when food is not available (Berry, Kangas, & Branch, 2012).

Researchers have many other techniques for the study of animal's timing behaviour. The most common are: duration estimation, discrimination procedures, production procedure, and peak procedure. In recent years, the peak procedure, in particular, has become a very popular method of studying timing in pigeons, rats, possums, and hens (see Aum, Brown, & Hemmes, 2007; Belke & Christie-Fougere, 2006; Lockhart, 2011; McHuge, 2012).

The Concept of Internal Clock

Some researchers posit that many species of animals achieve timing behaviour using an internal clock (Roberts & Church, 1978). Domjan (1998) suggested that animals have a timing mechanism which may be located somewhere in the nervous system and has the properties of a clock or a stopwatch. Thus, it may start, stop, and restart, or it may time the duration of an event. Furthermore, a pacemaker is said to be included in the internal clock and like a metronome, producing regular beats allowing animals to measure time (Church, 1984; Mazur, 1994).

Roberts (1981) designed five experiments to study the clock using the peak procedure (more details will be discussed later). In Experiment 1, he used the peak procedure to investigate timing in rats. On the extinction trials (when no reinforcer was given) the peak response rates occurred close to the time that

reinforcers would normally become available on food trials, with lower response rates before and after that peak point. Experiment 2 was designed to measure the effect of having blackout breaks at various times early in the trial. The results showed that blackouts increased peak time (the time of the maximum response rate measured from the start of the trial) by about the length of the blackout and did not change peak rate (the value of the maximum). Roberts suggested that the clock temporarily stopped timing when the break was introduced. During the break, some information about how much time had passed was lost but, when the normal trial resumed, the clock carried on timing without resetting. In Experiment 3, Roberts searched for more evidence that peak rate can be changed without changing peak time by pre-feeding animals and observing peak rate and peak time during the experimental sessions. The result confirmed that one can be changed without changing the other. Pre-feeding increased peak time (the rate of the clock), therefore Roberts concluded that the clock's pacemaker is internal. In Experiment 4, Robert showed that food omission in one interval decreased peak time in the next interval, suggesting that food somewhat reset the clock. Lastly, the results of Experiment 5 suggested that food could change the time of the peak by changing the criterion time, like time elapsed in a stopwatch.

In another experiment, Roberts (1982) used a time-discrimination procedure to further investigate the internal clock of rats. This time, the result implied that the internal clock can be stopped and then restarted just like a stopwatch. Other researchers have also supported Roberts's findings about the clock (see Maricq, Roberts, & Church, 1981; Meck & Church, 1984; Roberts & Church, 1978; Staddon, 1974). Theories of the internal clock allow many animal timing phenomena to be better understood.

Models of Timing

In addition to internal clock models, there are several models that make different assumptions about timing behaviour of animals and how this behaviour is represented in memory. In this section, I review two timing models; the scalar expectancy theory (SET), a dominant model in the field, and the behavioural theory of timing (BeT), an alternative model to SET.

The scalar expectancy theory (SET). SET is an information-processing model of timing developed by Gibbon (1977); see also Church, Meck, & Gibbon, 1994; & Gibbon, Church, & Meck, 1984. As shown in Figure 1, SET describes the relationship among three independent processes: a clock process, a memory process, and a decision process.

The clock process is made up of a pacemaker (that produces pulses at a steady average rate), a switch (which controls the flow of pulses from the pacemaker to the accumulator), and an accumulator which counts the pulses when the switch is closed or weakens when the switch is opened. The count from the accumulator is then transmitted to working memory and information about similar events in reference memory. Lastly, at the decision level, the pulses or information in memory are transmitted to a comparator that compares information from working memory and reference memory. If the values match, a “yes” response is made. If values do not match, a response is withheld. For example, in the FI schedule, if the time information in an animal’s working memory matches the information in reference memory regarding the availability of food, a “yes” decision to respond is made. However, if this information does not match then a “no” decision is made (Gibbon, Church, & Meck, 1984; Mazur, 1994).

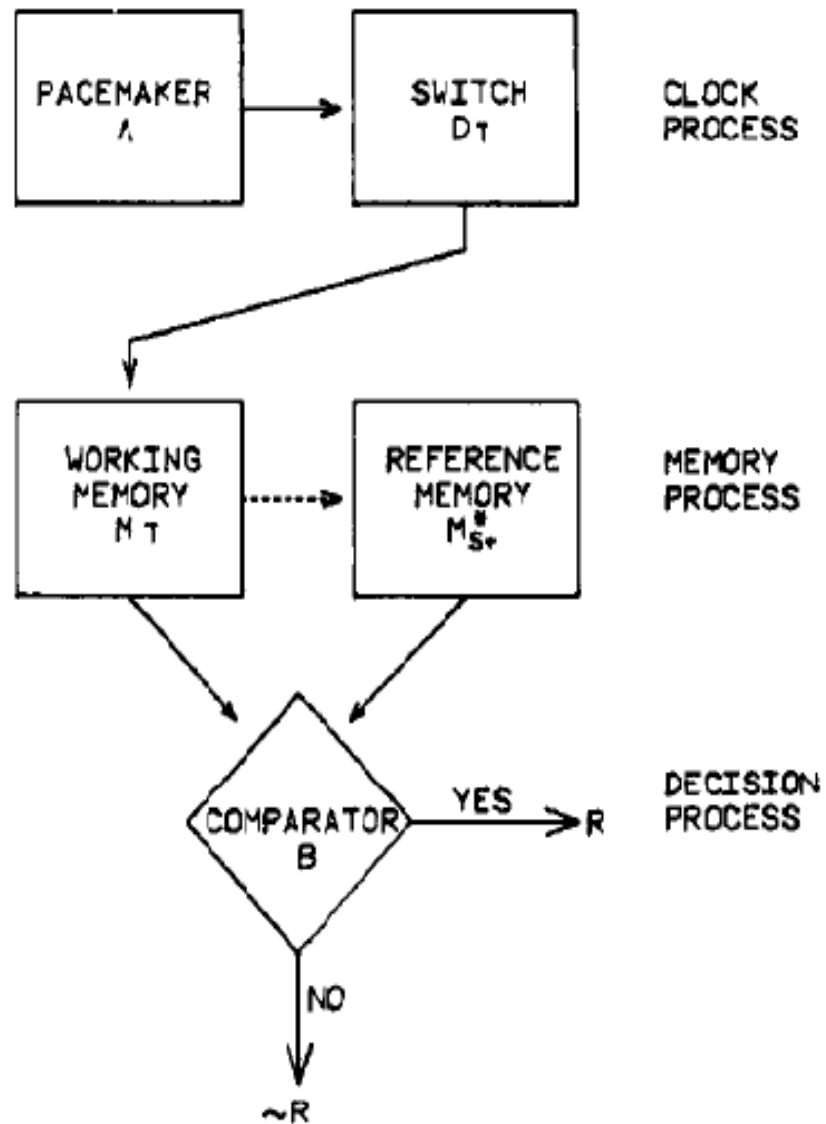


Figure 1. An information processing model for timing behaviour that has three processes: a clock process, a memory process, and a decision process. Reprinted from "Scalar timing in memory," by J. Gibbon, R. M. Church, and W. H. Meck, 1984, *Annals of the New York Academy of Sciences*, 423, p. 54. Copyright 2006 by John Wiley and Sons.

Behavioural theory of timing (BeT). Killeen and Fetterman (1988) developed a more behavioural alternative to SET that does not suggest that animals form mental representations of time but does suggest a pacemaker counter system except that pacemaker pulses move the animal through a series of adjunctive states and it's the behaviour associated with those adjunctive states that the animals use as discriminative stimuli as to the passage of time.

Some behavioural responses are rewarded after a certain time interval has elapsed. For example, the rooster's first key peck after a 60-s interval may result in reinforcement (food). While waiting for the end of the interval, animals may engage in time-related activities, called adjunctive behaviours, to help them measure the time to reinforcement. For example, the same animal might display repetitive behaviours such as jumping up and down then scratching a wall and this adjunctive behaviour is not related to the delivery of reinforcement, but the repetition of these behaviours help mark the passage of time before reinforcement becomes available. Adjunctive behaviours do not, themselves, produce reinforcement, and thus may be thought of as interim responses that occur early in the time interval. Terminal responses, however, are more probable towards the end of the time interval. For example, as the time for reinforcement approaches, the rooster may start to peck a key. After key pecking has been reinforced, the rooster might again perform unrelated behaviour in the same sequence. It takes the animals roughly the same amount of time to go through different behavioural states, so the BeT assumes that animals use their own behaviour to tell time. For SET, the timing is done by a system inside the animals, whereas for BeT, the timing is done by the animal's behaviours. To summarise, the behavioural view is that timing is something that we do, not something that we have.

FI Schedule/ Peak Procedure

One of the most common techniques to evaluate the ability of animals to time, and a more informative version of the FI, is the peak procedure. The peak procedure was devised by Catania (1970) and became widely known after its use by Roberts (1981) to investigate the internal clock of animals. In the peak procedure, animals are initially exposed to a FI schedule where the first response after a fixed amount of time is reinforced (Roberts, 1981). For example, if the interval is 30 s (FI 30 s), then a key peck 30 s (or more) after the interval has started yields reinforcement. The animals' responses during the interval have no effect. Thus, the delivery of reinforcement depends on both a response and the passage of time (Roberts, 1981). During the Peak Interval (PI) or EXT trial, responses are not reinforced and the trial continues for a longer period. During EXT trials, response rates tend to increase to a peak then decrease before increasing again towards the end of the trial (Kaiser, 2008). Kaiser (2008) stated that this pattern of responding on EXT trials is considered a sign of accurate assessment of the time that passed. The main measures of performance (the animal's timing ability) are peak time (time when peak rate occurs), peak response rate (the maximum response rate), and the mean and standard deviation of these response distributions. These measures calculated on the EXT response data (Roberts, 1981).

After an animal has been trained on this procedure, the rate of response rises to its highest point at about the time where food is normally given. The better the animal is able to judge the usual time of reinforcement, the closer the peak is to the usual time, and the smaller the standard deviation around that mean. There has been some interest in the performance of animals and factors that affect the

distribution of responses on the peak procedure. A particular interest has been the shape of the function for EXT trials.

Kirkpatrick-Steger, Miller, Betti, and Wasserman (1996) looked at whether discrimination learning shapes the single-peaked response distributions usually obtained with the peak procedure. Specifically, the authors examined whether pigeons could learn to respond near the time of reinforcement on FI trials and learn to withhold responding on EXT trials. First, the birds were trained on the FI-30 s trials alone, then the EXT trials were introduced. In general, the study showed that, response rates rose to a peak at or near 30 s and, after the peak was reached, the response rates slowly dropped to 120 s which was the end of the trial. From Days 25-60, responding of Group 30+/120+ (Birds 1, 2, 3, and 4) rose until 30 s and fell until 60 s, then rose again until the end of the trial and responding of Group 30+/120- (Birds 5,6, 7, and 8) produced a second peak. Follow-up experiments showed that a 1:4 FI: EXT duration ratio appeared necessary to produce those double peaks, and at much longer non-reinforced trials (1:8 FI: EXT duration ratio) only one peak was obtained.

After a long training on the peak procedure, the response pattern comes to resemble a Gaussian distribution (bell-shaped curve) with positive skew centred on a specified FI duration where response rates increase towards the end of EXT trials as shown in Figure 2. This particular pattern is known as response resurgence. Sanabria and Killeen (2007) were curious about what controlled the skewness and the resurgence. They thought that these divergences may be explained by the time of the forthcoming reinforcers so they did two experiments to test their hypothesis. Pigeons and rats served as subject to find out if there were differences between species and salient cues were used to mark the different

interval. Pigeons and rats were trained on a peak procedure under various FI/EXT durations. The results obtained from both species were nicely described by Gaussian distribution. The results showed under that various FI and EXT trials durations, both species demonstrated response resurgence. Resurgence at the end of EXT trial was sensitive to changes in FI and EXT trials duration. In conclusion, reinforcement that following EXT trials is what controlled the occurrences of the resurgence.

Lockhart (2011) investigated the performance of possums in two experiments that used the peak procedure to investigate their ability to time. Lockhart's goals in Experiment 1 were to investigate the performance of possums on the peak procedure and to find out why resurgence occurs. It was found that the response rates increased to the highest point at about the time the when responses were normally reinforced (on FI trials) then the responses decreased to the lowest point at about twice the FI schedule duration. Then the rates of response increased again near the end of EXT trials. Lockhart's goal in Experiment 2 was to measure the effect of extended EXT trials on resurgence. In this experiment, EXT trials lasted either 3 or 10 times longer than the FI trials. Resurgence occurred at the end of the EXT trials when they were 3 times longer than the FI, but decreased significantly when they were ten times longer. This suggests that resurgence was dependent on the EXT duration. In general, response rates increased to a peak at or near the time of expected reinforcement then decreased to the lowest point at a time that was around twice the FI duration. For the majority of subjects, the rate of responses then increased to a second high at the end of the EXT trial.

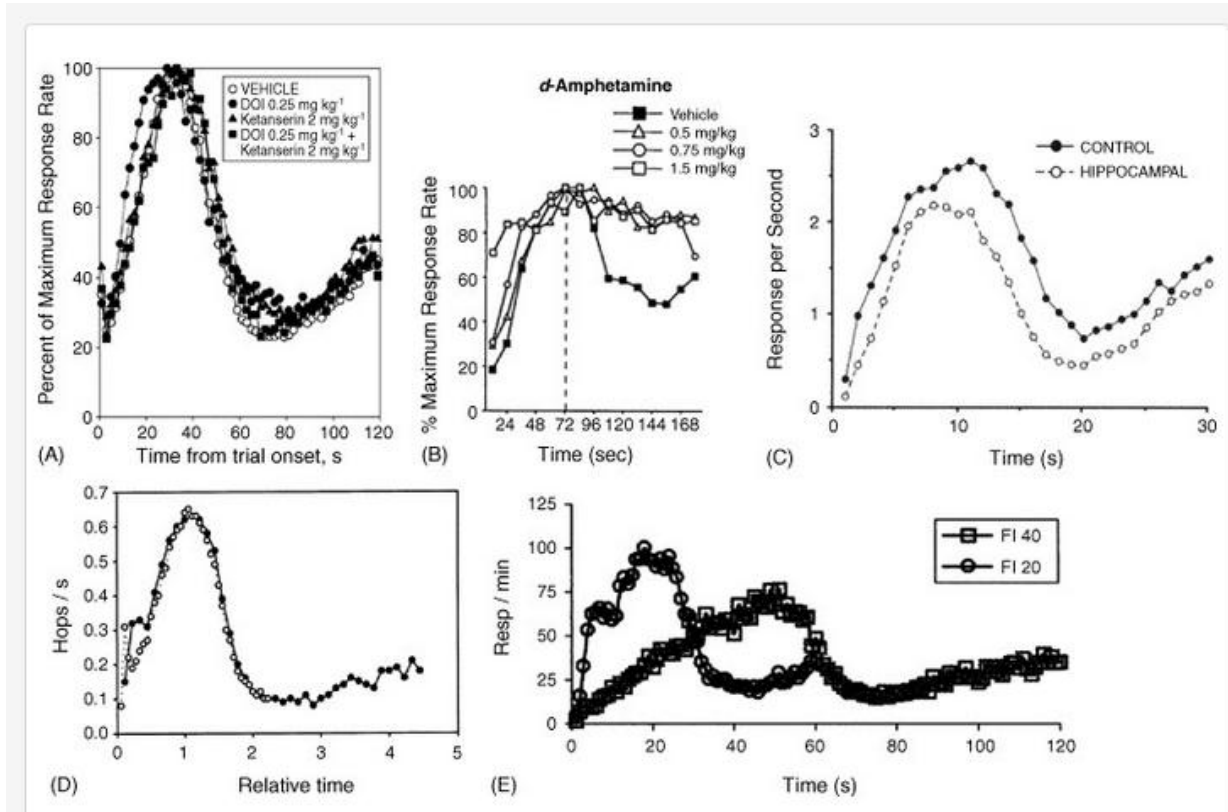


Figure 2. Peak interval performance in five experiments. (A) Female Wistar rats under various 5-HT receptor agonist and antagonist treatments. (B) PVG rats under various doses of d-amphetamine. (C) Pigeons with hippocampal lesion and sham control. (D) Starlings trained in two fixed interval (FI) schedules of reinforcement. (E) Pigeons trained in two FI schedules of reinforcement. Reprinted from “Temporal generalization accounts for response resurgence in the peak procedure,” by F. Sanabria, and P. R. Killeen, 2007, *Behavioural Processes*, 74(2), p. 127. Copyright 2006 by Elsevier B. V.

McHugh (2012) investigated the perception of time by six hens using the peak procedure. The hens underwent FI schedule training and then were introduced to peak testing. In FI training, the rate of responding was low at the beginning of the trial then gradually increased with the highest rate of the responding at or near the reinforcement time. In peak testing, the response rates reached their highest point at about the expected time of reinforcement then decreased after that point. In addition, during the EXT trials, the responding did not extinguish and none of the birds showed a second peak similar to the first.

Different researchers have come to a similar conclusion that responding during EXT trials always increases steeply toward the time where reinforcement would have occurred, when those trials were of a predictable nature such as on FI schedule (Kirkpatrick-Steger et al., 1996; Lockhart, 2011; McHugh, 2012). The question of interest is why animals would continue to respond in the trial long after any chance of food reinforcement? It has been suggested that animals' responding on EXT trials might be reinforced by escaping the EXT trials. In short, their responding at the end of long PI trials is superstitiously reinforced when it coincides with the end of the EXT trial. The end of the EXT trial might function as a negative reinforcer if one assumes an animal might work to escape from a period of extinction.

Escape (Negative Reinforcement)

Negative reinforcement has been considered as an effective way to motivate or to increase the level of a desired behaviour (Grant & Evans, 1994). Research in applied studies has shown that human behaviour can be acquired or maintained through negative reinforcement (Iwata, 1987). Negative reinforcement is also called escape conditioning. Escape conditioning strengthens behaviour

through the removal or reduction of an aversive stimulus. In the escape contingency, a response becomes more likely to occur if, in the past, that response has removed or reduced an aversive stimulus (Malott, 2008). Escape conditioning is common in our everyday life. Cleaning the house is strengthened by the removal clutter. Finishing an essay is strengthened by removal of complaints from a teacher. To say that escape conditioning has occurred, the following must be met: 1) the stimulus is removed, dependent on a response (e.g., the EXT trial comes to an end); 2) the response is strengthened (e.g., a rooster keeps pecking); and 3) the increase in response is not due to any other factor other than response-consequence relationship (Grant & Evans, 1994).

Grant and Evans (1994) further explained that behaviour strengthened by negative reinforcement can be extinguished. This happens when the emitting of a certain behaviour is longer terminates the aversive stimulus. For example, when a person's eyesight has changed and their glasses no longer allow them to read properly. When they come across something to read, the escape response of putting on glasses would be extinguished because that action would no longer allow them to see.

If we look in the natural environment, it seems that most species have been equipped to escape from stimuli that could potentially harm them (e.g., avoiding being eaten by predators, pretending to be dead, or blending in with their surroundings). In the laboratory setting, electric shock, loud noises, extreme temperature, and bright light are typical aversive stimuli used to study escape learning in animals (Leslie, 1996).

Looking at why might animals continue to respond in the trial long after any chance of food reinforcement, it is possible that the animal's responses at the

end of the EXT trial are being negatively reinforced by the termination of EXT trial or put it simply, by escape from the period of no food. Why does this matter? In applied behaviour analysis (ABA) settings, frequently the therapist assumes they've identified the contingency or have arranged a source of reinforcement but don't end up controlling behaviour. For example, a mother nags the child when he does not do his homework, and when he does, he gets iPad. After a while the mother stops nagging, and the boy stops doing his homework, even though he still gets the iPad. It is also vital for researchers to investigate how environments or contexts that they create may encourage (negatively reinforce) the unwanted behaviour. If therapists have the ability to identify what is maintaining unwanted behaviour, it could be very helpful in treatment selection and its outcome.

Research has shown that escape conditioning can set off inappropriate behaviour in children. In ABA, a main focus has been on how adults' behaviours influence problem behaviour of children; however, a related question is how children's behaviours influence the behaviour of adults (Carr, Taylor, & Robinson, 1991).

According to Carr et al. (1991), behaviour problems of children may function as aversive stimuli for adults, therefore, negative reinforcement such as reprimands may strengthen adults' behaviour by allowing them to escape from the child's problem behaviour. Adults' behaviour of giving a reprimand is reinforced by the cessation of the child's aversive behaviour. Miller, Lerman, and Fritz (2010) stated that it is important to understand the impact of children's behaviour on adult's behaviour because certain behaviour can maintain and reinforce the problem behaviour and a better understanding of what affects adult behaviour may lead to improvement of the behaviour intervention.

Miller et al., (2010) conducted an experiment which analysed negative reinforcement contingencies for adult-delivered reprimands. In this experiment, adults participated in teaching sessions with a confederate who acted as a student with developmental disabilities. During teaching sessions, the confederate engaged in problem behaviour, inattentiveness, limited speech, property destruction and self-injury. On the reprimands of the participants, the problem behaviour (of the confederate) either stops or continues. If the confederate's behaviour stops due to reprimands, then the behaviour of the participants is being negatively reinforced. The results showed that reprimands are sensitive to negative reinforcement (terminate problem behaviour) and children's behaviour can affect adults' implementation of interventions.

The orderliness of performance on the peak procedure attracted many interests from researchers, not only in animals' studies but also on humans as well. Some studies stated clearly that they were using the peak procedure but many were not. Take Miller et al., (2010) experiment as an example. The participants did not know that whether reprimands (this equivalent to key pecks) will stop the problem behaviour (this equivalent to ending an EXT trial). The problem behaviour either stops or continues (this equivalent to either FI or EXT trial). Miller et al., (2010) study showed a perfect parallel between performance in humans and animals on the peak procedure.

Negative reinforcement could be an ideal intervention for those whose problem behaviours are maintained by escape from certain stimuli. Many studies have used negative-reinforcement interventions to increase the level of a desired behaviour, or decrease the level of an undesired behaviour and it can be an

effective behaviour-change procedure (Kitfield & Masalsky, 2000; Roberts, Mace, & Daggett, 1995; Vaz , Volkert , & Piazza, 2011).

In addition to negative reinforcement, escape extinction (EE) has been used to treat numerous learning and behaviour related problems. EE describes the situation where behaviours previously maintained with negative reinforcement (e.g., a child cries and her mother removes broccoli from her plate) no longer ends the aversive situation (e.g., crying no longer leads to removal of broccoli). The following studies may help to explain why escape is interesting.

Bui, Moore, and Anderson (2013) showed that a procedure consisting of EE and positive reinforcement increased food acceptance and reduced food refusals in a child with autism. In this study, the mother of the child was told to encourage and give verbal praise every time the child ate. Also, the mother had to keep the spoon in front of the child's face and not pull away until the child accepted the food. The spoon represented the aversive stimulus from which the child could escape. If the child was disruptive, the mother was to reintroduce the same spoon to the child. The percentage of food acceptance in the baseline was low, then increased during the intervention phase and the acceptance rate was maintained in the follow-up. The application of EE and positive reinforcement was effective in increasing food acceptance.

Piazza, Patel, Gulotta, Sevin and Layer (2003) compared the effects of positive reinforcement with escape extinction and positive reinforcement and escape extinction alone in the treatment of a feeding problem. The results showed that positive reinforcement alone did not increase food consumption but when escape extinction was implemented regardless of positive reinforcement,

consumption increased. The findings from this study supported previous findings about extinction as an effective treatment of food refusal.

The Aims of the Study

One short-coming of the peak procedure is that there is only one response alternative available to the animal, which might explain why, even after extensive experience, the animals still respond at high rates at times when they would never earn food reinforcers. In my experiment, I hypothesise that the reason response rates increase towards the end of EXT trials on the peak procedure because those responses are negatively reinforced by escaping the EXT trials and resurgence maybe the result of escape from the EXT trials. I will test this “escape” hypothesis in different conditions. Firstly, by giving the birds the opportunity to escape the EXT, or non-reinforced trials to see if the birds will take the opportunity to escape a period of non-reinforcement. In a separate condition, a second source of reinforcement will be provided if the birds peck a second key, allowing them to “end” the EXT trial early and to earn reinforcers from this second alternative. I was hoping to see a second key improves the birds’ performance on the peak procedure (the birds’ ability to judge the passage of time).

Method

Subjects

Six roosters of mixed breed (*Gallus gallus domesticus*) served as subjects. They were experimentally naïve at the start of the experiment. They were housed individually. In their home cages, they had access to a feeding basket, water, and an enrichment device. The roosters were given vitamins and grit on a weekly basis. They were housed on a 12 hr light, 12 hr dark cycle, with lights on at 6.00 a.m. and off at 6.00 p.m.

The roosters' body weights were maintained at 85% +/- 5% of their ad-libitum body weight at most time. These weights were established after a 3-to-4 week period of free food access immediately prior to the first experimental condition. The roosters earned the majority of their food during a daily experimental session and were given supplementary food as required. The roosters were included in the daily experimental session irrespective of weight.

Apparatus

An operant chamber with approximate dimensions of 118 cm wide, 75 cm high and 53 cm deep was used. Two response keys, which could be illuminated red and green, were mounted on one of the narrow internal walls of the chamber. The two keys were positioned 20 cm apart and 24 cm from the ceiling of the chamber. An opening centred beneath the two response keys (13.5 cm high with 10 cm wide) provided access to a food magazine from which the roosters could eat when it was activated. The food magazine had an infra-red beam that ensured a scheduled number of seconds of timed access to wheat from the time the rooster placed his head in the food hopper. Experimental events were controlled and recorded via a MED-PC interface (behavioural experiment control software) and a computer. Figure 3 shows the outside of the operant chamber and the response panel inside the box.

Procedure

Magazine training and key-peck shaping. The roosters were initially trained to eat from a food magazine, by placing them in the operant chamber and raising the food magazine intermittently. Once the roosters reliably (the criterion for eating reliably was to eat within specified time frame) ate from the magazine when it was presented, one of the keys was illuminated red or green, with the side

and colour selected randomly by the computer. Key pecking was auto-shaped using successive approximations. When a response approximating a key peck occurred, the response was reinforced by providing access to the food magazine. When the roosters pecked the key reliably they moved to training on FI schedules.

Fixed-interval (FI) training. During the FI training phase, a trial began when one of the two keys was randomly selected to be illuminated and ended with a key peck 40 s after the interval has started. If the bird did not peck within 300 s from when the trial started, he was removed from the chamber. For all trials, the first key peck after the FI had timed out was reinforced with 2 s access to food. There were 50 trials per session and each trial was separated by a 6 s inter-trial interval (ITI) during which the key light was off. There were 5 training sessions and each session ended after 10 reinforcers were obtained or after 300 s had passed. In session 1, 2, 3, 4, and 5, the FI schedules were 5, 10, 20, 30, and 40 s. After the roosters had completed all training sessions, they started training on the peak procedure.



Figure 3. Photographs of the experimental chamber and the two response keys.

Peak procedure. During the peak procedure training an FI trial or an extinction (EXT) trial began when one of the two keys was randomly illuminated red. The trial type was selected randomly by a computer. An FI trial ended with a reinforcer delivery (if the rooster never pecked, then the session ended after 3600 s) while an EXT trial ended after a specified time had passed (the length of PI trial varied). The EXT trials were the same as the FI trials, except that they were three times longer and no key pecks were reinforced. In the peak procedure training, there were 3 training sessions and each session comprised of 24 FI trials and 6 EXT trials. In the first session, FI 10-s and EXT 30-s schedules of reinforcement applied. In the second session, FI 20-s and EXT 60-s schedules, and in the third session, FI 40-s and EXT 120-s schedules were used. All roosters experienced all sessions in the same order.

Experimental conditions.

Condition 1: FI 40 s/EXT 120 s (red key). In Condition 1, the standard peak procedure was used and only one of the two keys was activated. As in the peak procedure training, an FI trial and an EXT trial began when one of the two keys was randomly illuminated red. The non-selected key remained dark during each trial. Each session was 24 standard FI 40-s trials and 6 EXT 120-s trials and there were 10 sessions in total.

Condition 2: FI 40 s/EXT 120 s (red key) and Escape (green key). In Condition 2, the function of one of the two keys remained the same as in Condition 1 but the other key was illuminated green on EXT trials after 40-s interval. Responses to the green key allowed the bird to end the EXT trial early (provide the opportunity to escape). When the bird pecked the green key, the EXT trial ended, and an ITI of 10 s started followed by the next trial, which may have

been either an FI or EXT trial. Each session was 24 standard FI 40-s trials and 6 EXT 120-s trials and there were 10 sessions in total.

Condition 3: FI 40 s/EXT 120 s (red key). Back to baseline (same as Condition 1).

Condition 4: FI 40 s/EXT 120 s (red key). Back to baseline (same as Conditions 1 and 3).

Condition 5: FI 40 s/EXT 120 s (red key) and VI 60 s (green key). In Condition 5, FI and EXT trials operated on the red key and VI trials on the green. Every trial began with a red key and a green key, with the side allocation randomly selected by a computer. On FI trials, after 40 s had elapsed, a single peck to the red key produced a reinforcer. The green key operated a VI 60 s concurrently (at the same time as the red key was on). The VI 60 s continued to operate until a red key response was reinforced. On EXT trials, no reinforcement was available on the red key (extinction), but the red and green key, operating a VI 60-s schedule of reinforcement, remained lit throughout the 120-s trial. On FI trials, a trial ended when the bird pecked the red key after 40 s had elapsed and a reinforcer had been delivered, and on EXT trials, the trial timed out after 120 s.

Results

Data from Condition 4 (FI 40 s/EXT 120 s) were not included in any of the calculations because the data for this baseline had not recovered. Figure 4 shows that, in general, at the start of the baseline conditions (the average of Conditions 1 and 3, red key) and escape condition (Condition 2, red key), the rate of responding was low with a steady increase in responding as the trial progressed until it reached the peak rates which occurred at, or close to, 40 s and decreased after that. In the baseline conditions, the response rate dropped after the usual time

of reinforcement then resurged towards the end of EXT trials. In contrast, when the birds were given the opportunity to escape the EXT trials (in Condition 2), the birds did not respond as much after the 40-s interval on the red key as when there was no escape opportunity. Figure 4 illustrates that the birds were escaping most of the EXT trials and Condition 2 did improve the timing performance on the peak procedure.

The same baseline conditions (the average of Conditions 1 and 3, red key) were plotted in Figure 5. Figure 5 shows that during Condition 5 (FI 40 s/EXT 120 s and VI 60 s) all birds were responded at a reasonably high rate throughout the trials on the red key during EXT trials. There was no peak, no resurgence, or any expected pattern (bell shape) that can be seen. Figure 5 illustrates that a second source of reinforcement (VI 60 s) did not improve the timing performance on the peak procedure and did not make it a more sensitive procedure for measuring the birds' ability to judge the passage of time.

The mean (M), standard deviation (SD), and Weber Fraction (WF) were calculated for data from EXT trials for all conditions. Table 1 shows the M , SD , and WF for all birds, for Conditions 1 to 3. The mean of each condition is displayed in the bottom row. Table 2 gives the same information as Table 1 but for Condition 5.

To investigate changes in performance on EXT trials in the different condition the means, standard deviations, and Weber fractions were calculated for the first 80 s of EXT for each bird for each condition and these are summarised Table 1 and 2. The response rates functions were roughly symmetrical around the time at which the birds were normally reinforced on FI trials. Performance on the entire EXT trial was not used because it would have included periods of

resurgence and that would have shifted the mean some way from the FI value which is where response rates typically peaked.

In the present experiment, a one-way repeated-measures analysis of variance (ANOVA) showed a significant difference between the means in each condition ($F(1, 4) = 31.88, p = .005, \eta^2 = .89$). The overall means across all birds were 46.74, 34.38, 47.04, and 43.79 for Condition 1, 2, 3, and 5 respectively. The means for all birds show response rates raised to a peak at reasonably close to the time of reinforcement (40 s). In particular in Condition 5 (FI 40 s/EXT 120 s and VI 60 s), the mean was 43.79 which was the closest to 40 s mark. The average mean for Condition 3 (FI 40 s/EXT 120 s) was the furthest away from the time of reinforcement. The birds had been on this particular schedule of reinforcement twice, but the timing performance had not been improved. The overall mean for Condition 2 (FI 40 s/EXT 120 s and Escape) was closer to 40 s compared to the average mean of the baseline conditions. The problem with only basing the results on the mean, however, is that the mean uses all the numbers in its calculation; therefore it can be sensitive to extreme numbers.

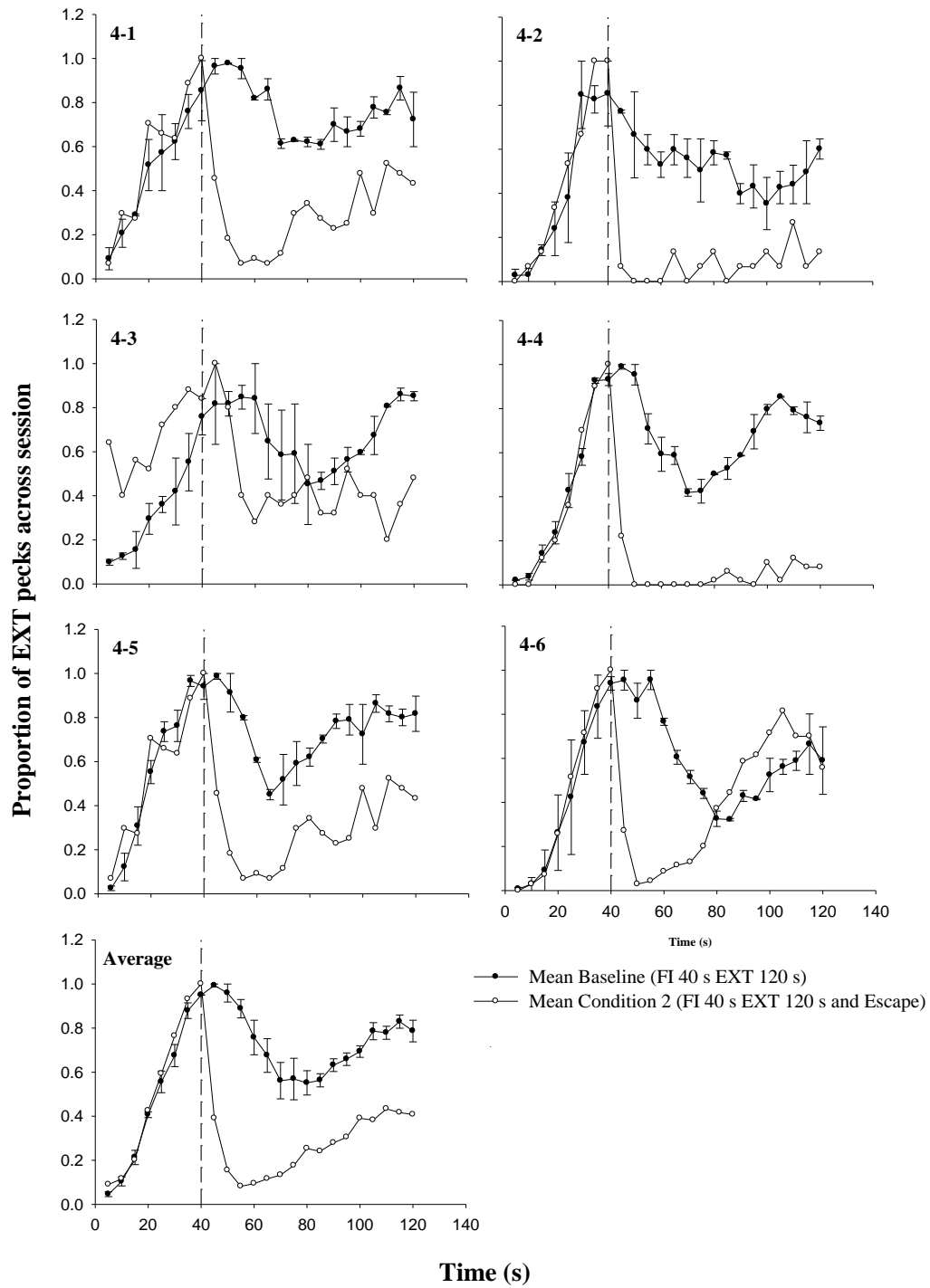


Figure 4. Proportion of the EXT pecks as a function of time in seconds across the trial, for all birds, and for the total across birds, in the baseline conditions (FI 40 s/EXT 120 s) and Condition 2 (FI 40 s/EXT 120 s and Escape). The dashed line indicates time of reinforcement under the FI trials.

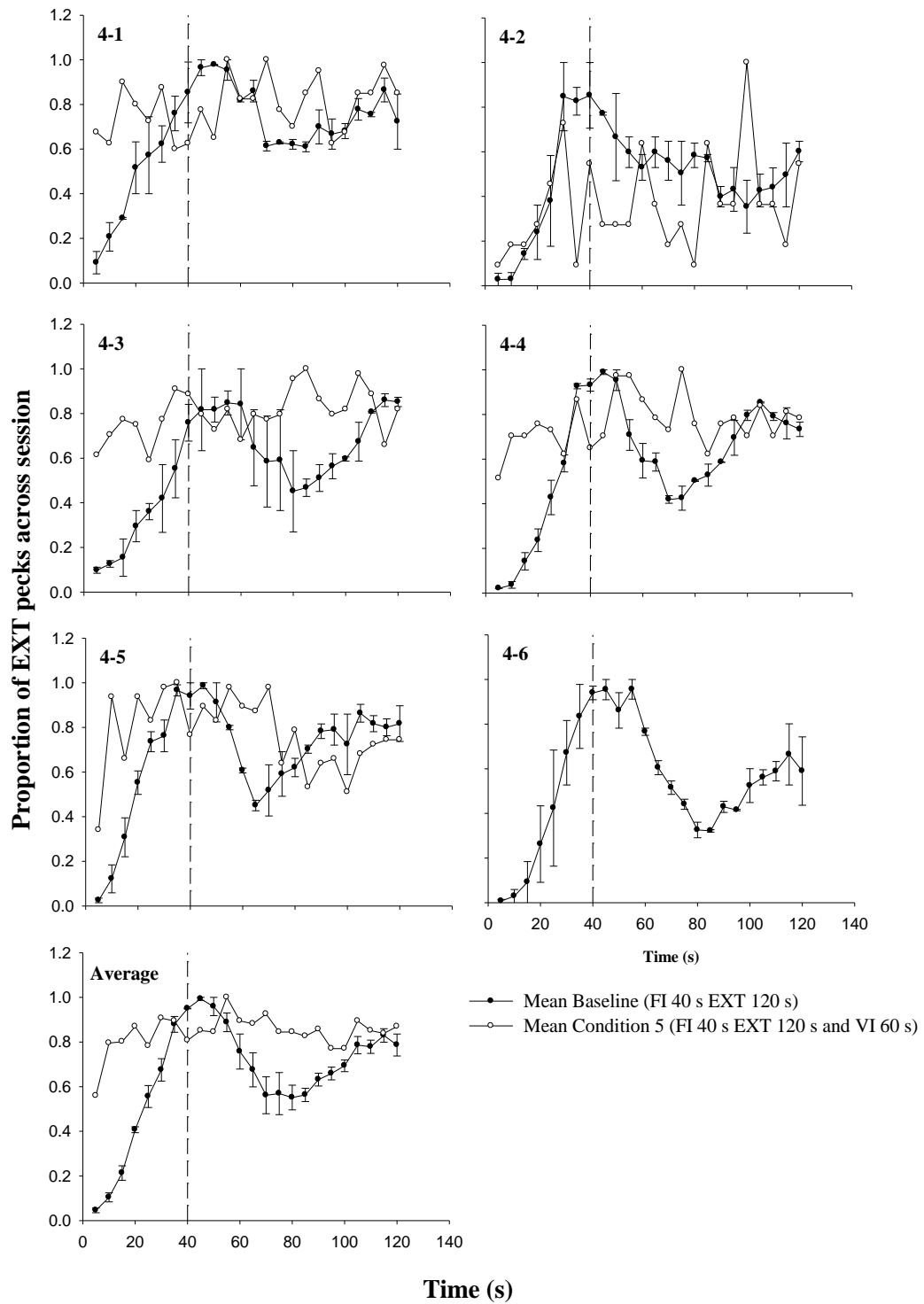


Figure 5. Proportion of EXT pecks as a function of time in seconds across the trial, for all birds, and for the total across birds, in the baseline conditions (FI 40 s/EXT 120 s) and Condition 5 (FI 40 s/EXT 120 s and VI60 s). The dashed line indicates time of reinforcement under the FI trials.

Table 1

The mean (M), standard deviation (SD), and Weber fractions (WF) of EXT responses for all birds, for Conditions 1 to 3 with the average displayed in the bottom row

Birds	Condition 1			Condition 2			Condition 3		
	FI 40 s/PI 120 s			FI 40 s/PI 120 s and			FI 40 s/PI 120 s		
	Escape								
	<i>M</i>	<i>SD</i>	<i>WF</i>	<i>M</i>	<i>SD</i>	<i>WF</i>	<i>M</i>	<i>SD</i>	<i>WF</i>
4-1	47.85	19.52	0.41	31.29	15.21	0.49	48.91	20.23	0.41
4-2	45.36	20.01	0.44	35.81	14.71	0.41	47.79	18.99	0.4
4-3	47.59	20.12	0.42	37.71	16.89	0.45	46.15	18.69	0.4
4-4	48.22	17.64	0.37	32.68	11.01	0.34	47.97	17.85	0.37
4-5	45.02	19.4	0.43	34.93	18.16	0.52	44.77	19.67	0.44
4-6	46.40	20.19	0.44	33.84	14.89	0.44	46.62	17.89	0.38
Average	46.74	19.48	0.42	34.38	15.15	0.44	47.04	18.89	0.40

Table 2

The mean (M), standard deviation (SD), and Weber fractions (WF) of EXT responses for all birds, for Condition 5 with the average displayed in the bottom row

Birds	Condition 5		
	FI 40 s/PI 120 s and VI 30 s		
	<i>M</i>	<i>SD</i>	<i>WF</i>
4-1	43.57	23.91	0.55
4-2	43.15	21.74	0.5
4-3	43.90	23.86	0.54
4-4	44.76	23.46	0.52
4-5	43.59	22.68	0.52
4-6	-	-	-
Average	43.79	23.13	0.53

A one-way repeated-measures analysis of variance (ANOVA) showed a significant difference between the standard deviation in each condition ($F(1, 4) = 44.21, p = .003, \eta^2 = .92$). The average standard deviation across all birds was 19.48, 15.15, 18.89, and 23.13 for Conditions 1, 2, 3, and 5 respectively. The average *SD* was highest in Condition 5 (FI 40 s/EXT 120 s and VI 60 s) and lowest in Condition 2 (FI 40 s/EXT 120 s and Escape). In the peak procedure, the better the birds are able to judge the usual time of reinforcement, the smaller the standard deviation around that mean. Standard deviation showed the birds were at their best at timing in Condition 2 (FI 40 s/EXT 120 s and Escape).

Weber's law is a theory concerned with measuring the difference threshold or the smallest difference between two stimuli that can be detected. It has been found in many studies that Weber fraction remains constant as long as the intensity of the stimulus is not too close to threshold (Goldstein, 1989). On the peak procedure, the smaller the *WF* is, the better the birds are at timing. A one-way repeated-measures analysis of variance (ANOVA) showed a significant difference between the Weber fractions in each condition ($F(1, 4) = 59.54, p = .002, \eta^2 = .996$). The overall mean *WF* (*SD*) for the Condition 1 and 3 (FI 40/EXT 120), Condition 2 (FI 40/EXT 120 and Escape), and Condition 5 (FI 40/EXT 120 and VI 60) was .41 (.03), .44 (.07), and .53 (.02) respectively. The birds were at their best at timing in the combined baseline condition. The size of the effect (η^2) was .996 (or $r = .998$) which was quite large.

Discussion

My objective was to examine why, after an extensive training on the peak procedure, animals still respond at high rates at times when they would never earn any reinforcers. I hypothesised that those high responses are negatively

reinforced by escaping the EXT trials. The end of the EXT trial might function as a negative reinforcer if one assumes an animal might work to escape from a period of extinction, and resurgence may be the result of escape from the EXT trials. The “escape” hypothesis was tested by providing the birds an alternative key (green key) that allowed them to end the EXT trial early (Condition 2) and, in a separate condition, to earn reinforcers from an alternative key (Condition 5).

In the baseline conditions (FI 40 s/EXT 120 s), the overall results showed that, at the start of both FI and EXT trials, the rate of responding was low with a steady increase in responding as the trial progressed. As expected, the peak response rates occurred at or close to 40 s, which was the time of reinforcement. The response rate decreased after the 40-s point. During FI trials, after the reinforcer delivery, the trial ended, and the birds were unable to make any further responses. During EXT trials, response rates dropped after the expected time of reinforcement, and then resurged toward the end of the trials. Lastly, the EXT peak was shifted a little bit to the right of 40 s for all baseline conditions. The mean peak responses across birds for the two baseline conditions were 46.74 and 47.04 which are the furthest from 40 s compared to other conditions. When comparing the mean peak responses in baseline conditions with those in the escape ($M = 34.38$) and VI ($M = 43.79$) conditions; it can be seen that the birds were better at timing (the peak rate occurred close to, or at, the time of reinforcement) when they were given an alternative key to respond on.

The performance on the peak procedure seen in this experiment was consistent with many prior studies (Kaiser, 2008; Kirkpatrick-Steger et al., 1996; Robert, 1981). Kaiser (2008) manipulated the percentage of the EXT trials compared to FI trials. The performance on the EXT trials and response patterns

seen by Kaiser are very similar to those seen in the experiment. In Kaiser's experiment, the result showed the peak responding was acquired more quickly when there were only a few EXT trials per session. In the present experiment, EXT trials made up only 20% of total trials.

Responses distributions for all conditions, except Condition 5 (FI 40 s/EXT 120 s and VI 60 s), were positively skewed and increased towards the end of the EXT trials. This pattern is known as resurgence. Sanabria and Killeen (2007) proposed that the forthcoming reinforcers following EXT trials is what controls response resurgence. As there were 24 FI trials and only 6 EXT trials per session, current EXT trials were most likely to be followed by FI trials, so responding at the end of EXT trials may have been reinforced by access to reinforcement on the next trial. Kirkpatrick-Steger et al. carried out experiments to find out under which conditions double peaks would occur. Results showed that the 1:4 (FI: EXT) duration ratio produced double peaks on the peak procedure but 1:8 (FI: EXT) duration did not produce double peaks. It was concluded that a 1:4 (FI: EXT) ratio is a key to produce double peaks. However, in the present experiment, the response pattern for all conditions did not show double peaks as reported by Kirkpatrick-Steger et al. The reason for the absence of second peak could be because the differences between the present study and Kirkpatrick-Steger et al. study. The differences were: animal species (roosters versus pigeons), the length of ITI (10 s versus 5 s), and the operation of the houselight (off during ITI and on for the magazine access versus on during ITI and off for the magazine access). Further studies may be needed to clarify this issue.

One short-coming of the peak procedure is that there is only one response alternative available to the animal, which might explain why, even after extensive

experience, the animals still respond at high rates at times when they would never earn food reinforcers. In Condition 2 (FI 40 s/EXT 120 s), I provided the birds with an alternative key which was illuminated green on EXT trials after the 40-s interval. Responses to the green key allowed the bird to end the EXT trial early. In general, results showed that, during FI trials, the peak time occurred at, or very close to, the 40-s interval, then responding dropped immediately. As in the baseline FI conditions, after the reinforcement delivery, the trial ended, and the birds were unable to make any further response. On EXT trials, the response pattern was similar to that of FI trials; the peak time occurred at, or very close to, the time that food was normally available on the FI trial, then responding dropped immediately, but was not always extinguished. In addition, responses after the peak time were quite low; this is because the birds escaped most of the time. This shows that green key signalled that the EXT trial had started and pecking the red key would not be reinforced. The overall mean peak responses for Condition 2 was closer to 40 s compared to the average mean of the baseline conditions. This indicates that by introducing an escape key, the timing performance improved a little. Also, the average standard deviation was lowest in Condition 2. In the peak procedure, the better the birds are able to judge the usual time of reinforcement, the smaller the standard deviation around that mean peak responses. The standard deviations showed the birds were at their best at timing in Condition 2.

One of the goals of my study was to find out why, after extensive experience, animals still respond at high rates at times when they would never earn food reinforcers. Alessandri and Riviere (2013) used timeouts from an aversive task as reinforcement to study operant conditioning in humans. In the experiment, participants were required to continuously press the force cell as hard

as they could with their thumbs until the word 'break' appeared on the computer screen. The experiment showed that timeout from an unpleasant task acted as a powerful reinforcer when it is available for humans. Based on the result, this may explain why the birds in this experiment still respond after 40 s on the EXT trials.

In Condition 5 (FI 40 s/EXT 120 s and VI 60 s) a second source of reinforcement was provided to test the "escape" hypothesis. In this condition, responses to the green key allowed the birds to earn reinforcers from this second alternative. In general, results showed that, at the beginning of the FI trials, the rate of responding was quite high. This high rate of responding was unlike the rate of responding during FI trials in any of the previous conditions, where the rate of responding had been low with a steady increase in responding as the trial progressed. On the EXT trials, the birds responded at a reasonably high rate until the trials ended, again unlike the rate of responding during EXT trials in any of the previous conditions, where the response rate slowly increased to a peak at the time of reinforcement then decreased. The average mean peak responses for Condition 5 was closer to 40 s compared to the average mean of the baseline conditions. This indicates that, by providing a second source of reinforcement, the timing performance improved. However, the overall mean Weber fraction was smallest in the baseline conditions (FI 40 s/EXT 120 s). On the peak procedure, the smaller the *WF* is, the better the birds are at timing. This shows that the birds did time better in the escape condition than in the VI condition.

According to Davison and McCarthy (1988), occurrences of behaviour do not solely depend on reinforcement of that behaviour but also on reinforcement of other behaviours. When an alternative source of reinforcement is not available,

behaviour is not being redirected towards the alternate source of reinforcement, thus responding is maintained during EXT trials. Furthermore, responding at a constant rate could prevent the animals from missing out on reinforcement. However, the cost for responding early may be the consistency and accuracy of timing in the peak procedure. Sanabria, Thraillkill, & Killeen (2009) established an opportunity cost for such responding. In the peak procedure procedure, opportunity cost is considered to be one of the factors that contributes to response rate function. Sanabria et al. defined opportunity cost as “the cost of not engaging in other activities while producing the target response” (p.217). In two experiments, Sanabria et al. examined an opportunity cost of peak interval timing using concurrent schedules of reinforcement with pigeons. In the first experiment, pigeons were presented with concurrent FI and random ratio schedules of reinforcement and in the second experiment, the same schedules plus random interval schedules were used. Whenever pigeons pecked on the FI key, they gave up the opportunity for potential reinforcement on the random ratio or random interval schedule. It was found that higher opportunity costs changed start and stop times in direction consistent with the optimisation of reinforcement; responses clustered around the target time. The higher variability at the start of the trial was explained by impulsive and the opportunity cost was also found to discourage these early impulsivity responses in the peak procedure. In Condition 5 (FI 40 s/EXT 120 s and VI 60 s) of the present experiment, the birds chose between two food sources, one that may replenish at any time around an average of 60 s or one that fully replenishes after 40 s but with a risk of no food (if it was an EXT trial). My interpretation is that the cost of pecking the FI key is higher

(because they may be missing reinforcement on the other key), which results in improved timing on the FI key as a way to optimise reinforcement.

The most well-known model of timing in animals is SET. SET provides the theoretical account for understanding of the mechanisms that animals use to time intervals. The three principle psychophysical properties of timing that SET deals with are: flexible accuracy, multiplicative variance, and ratio comparisons. Interval timings are very flexible as they may cover a very broad range of times, however, the cost of this flexibility is precision (Malapani & Fairhurst, 2002). Flexible accuracy and scalar variability (concerned with the variability of behaviour around the mean) were seen in the present experiment. Roosters' estimates of 40 s are shown in Figures 4 and 5; a high rate of response can be seen around 40-s mark. The birds had learnt that reinforcement was made available by pecking the key a lots more when they have been reinforced in the past at 40 s. According to Gibbon (1992) the decision to respond in timing tasks is based on the ratio comparisons between reinforcement rates or time intervals. In Condition 5 of the present experiment, the birds allocated responses to both keys. Figure 5 illustrated that the birds spent more time on the VI key.

The first weakness of this experimental design was that the data might present experiment might have been affected by carry-over effects. The birds gained some experiences in one condition and this might have spilt over into the next condition. In Condition 2, a peck on the green key led to escaping the EXT trials, the birds' responding may have become biased towards the green key, therefore, they pecked more on green than red in Condition 5. I suggest that future studies use counterbalancing to prevent order effects.

The second weakness was that, originally, I planned to have only 4 conditions (standard peak procedure, escape condition, standard peak procedure, and VI condition) in my experiment; however, because of a programming error when the VI schedule was originally introduced, I needed to return the birds to an earlier condition before introducing the concurrent VI schedule. Returning the birds to the baseline and rewriting the new program for the concurrent VI schedule took time, which mean that the birds spent less time than intended in the new VI schedule. If the birds had had longer in the final VI condition, their data may have been more stable, and potentially different to those reported here.

There are two implications of this experiment. In Condition 2 (FI 40 s/EXT 120 s and Escape), an alternative key was illuminated green on EXT trials after the 40-s interval. This illuminated green key acted as an external cue for the birds. Whenever the green light came on, it signalled that the current trial was an EXT trial and no reinforcers were available. Therefore, it is unclear that these birds were able to coordinate their behaviour (key pecks) with time changes or were they just relied on the green light as interval marking cue.

The next implication is that in Condition 5 (FI 40 s/EXT 120 s and VI 60 s), although the mean was more accurate ($M = 43.79$), the SD ($SD = 23.13$) during EXT trials was much larger, so the birds' responses were not clustered around the target time. I believed that the opportunity cost represented by the VI 60 s was not large enough to force more accurate timing behaviour on red key. The birds might have favoured the green key over the red key. To produce more behaviour on the red key, the duration on the VI schedule must be larger.

Further studies in timing and peak procedure could involve modifying and replicating the present experiment. In the escape condition, every trial should

begin with a red key and a green key but any responses before 40 s will not have any effect anything and only a response after 40 s will lead to the termination of the EXT trial. This way, it can be established that the birds were able to coordinate their behaviour (key pecks) with time changes and to conclude that they do have a desire to escape from a period of no food. Also, if the duration on the VI schedule of reinforcement were larger, it might produce more accurate timing behaviour on the red key. Moreover, different types of animals should be served as subjects to find out any differences between species. This can assist in the development of timing models of the peak interval performance.

One short-coming of the peak procedure is that there is only one response alternative available to the animal and this study has attended to this shortfall. My main conclusions are that roosters have a sense of time (they were able to track the reinforcers very well in FI trials) and by providing an alternative key to response; the birds' performance on the peak procedure was improved. Further studies using an alternative key on the peak procedure may help to gain further insight into the discriminative control of operant behaviour and by refining the peak procedure, the reliability or validity most likely to be improved.

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