Differential Reinforcement of Low-Rate Behaviour In The Brush Tail Possum

Explicit Alternative Responses During Differential Reinforcement of Low-Rate Responding

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Abstract

Differential reinforcement of low rate responding (DRL) can be defined as withholding reinforcement until probability of a target behaviour has decreased to a particular criterion. Typically, the DRL lowers the overall rate of a specific target response by incrementally increasing the time interval between responses and delivering reinforcement contingent upon a response occurring at or above the specified time interval. The present study parametrically examined six brush tail possum's performance on DRL to investigate in the first instance whether or not the possums could perform on DRL and if so, how well they could do at the task. The study also sought to investigate if DRL performance could be improved, by providing a second response lever as an explicit option to perform an alternative behaviour. Two Experiments were carried out. In Experiment 1, possums were expected to perform on a DRL schedule with one response lever (DRL lever) that produced access to food. In Experiment 2, a second response lever was available independent to the DRL lever and accessible for the duration of the experiment. The second lever provided no access to food. The possums were expected to respond on the second lever during the time delays (inter response time (IRT)) to assist mediating the time interval. Initial inspections of the data in Experiment 1 and Experiment 2 showed the possums performed efficiently on the DRL schedule up to around 15-s. Closer inspection of mean IRT data showed more unsuccessful responses than successful responses at around DRL 10-s and higher. Most of the possums maintained consistent responding below the DRL but sustained enough responding above the DRL to go on to higher DRL criterions. In spite of the larger number of unsuccessful responses some of the possums still failed to reach higher DRL criterions. Further inspection of the procedure revealed that at longer DRL as long as the possums had enough time (in days) to obtain the required number of reinforcers to meet the DRL, the procedure would automatically increment to the next DRL criterion giving the impression that they were able to perform the DRL. Furthermore, excessively long IRT were reinforced in the procedure. The provision of a second response lever in Experiment 2 was of no consequence contrary to expectations. This thesis purports that possums did not respond to the DRL contingencies and that performance that appears as if they did respond was an accidental by-product of the procedural arrangement.

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Introduction

The effect of a DRL procedure is to lower the overall rate of a target response by incrementally increasing the time interval between responses and delivering reinforcement contingent upon a response occurring at or above the specified time interval until the target response has decreased to a pre-determined requisite rate. DRL are of great interest to applied and experimental research. According to Kramer and Rilling (1970), early research showed more published studies in the Journal of Experimental Analysis of Behaviour (JEAB), on DRL than any other schedule of behaviour.

The applied experimental research on DRL generally investigates the characteristics of responding, the effects of various independent variables on base-line performance and the rates of behaviour generated by the DRL procedure (Kramer & Rilling, 1970). Some of these applied experiments will be discussed at length later in this thesis. Behaviour as an experimental measure dates back to Skinner (1938), and Ferster and Skinner (1957), who investigated response and reinforcement as a way to predict behaviour. Skinner (1938) imposed a temporal schedule of reinforcement in a study with rats and successfully decreased response rates by delivering reinforcers only when an interval time of 15-s was exceeded.

Ferster and Skinner (1957) first described DRL as a schedule of reinforcement. Under a DRL schedule, reinforcers attained over an experimental session can measure the ratio of efficient responding and provide information on the quality of the DRL performance (Doughty & Richards, 2002; Ferster & Skinner, 1957). If the subject is responding efficiently, a high number of reinforcers will be attained across an experimental session. If the subject is performing inefficiently, fewer or nil reinforcers will be attained across an experimental session (Doughty & Richards, 2002; Ferster & Skinner, 1957).

The efficiency ratio is measured by dividing the number of reinforcers by the number of responses made over an experimental session (Kramer & Rilling, 1970). Efficiency ratios and inter-response time (IRT) that is, the time (*t*) that must occur between responses (Ferster & Skinner, 1957), are usually a dependent variable (DV) measure because they can be manipulated to increase or decrease behaviour. An example of this is in Laties, Weiss, Clark, and Reynolds's (1965) experiment where adjunctive behaviour was interrupted by removing a block of wood. The subject gnawed on the block of wood during the IRT in a precise way that appeared to function as a time mediator. When the experimenters measured DRL efficiency against the effects of interrupting adjunctive behaviour (removing the block of wood to interrupt the gnawing action) they found a sudden decline in reinforcement rate. When the wood was placed back in the cage efficiency increased and was shown by a sudden increase in reinforcement rate. In another experiment by Orduna, Valencia-Torres and Bouzas (2009) efficiency was measured by manipulating DRL values. The experimenters reported a decline in efficiency when DRL values were increased in large shifts and efficiency maintained at longer periods when DRL values were increased in smaller increments.

Typically, a DRL schedule operates by increasing time intervals between the target response and reinforcer delivery (Ferster & Skinner, 1957) until such time that the target response has decreased to the required DRL limit. The delivery of a reinforcer is made contingent upon a specified IRT. Any response that occurs before the specified IRT has elapsed resets the wait period back to zero, reinforcer is withheld and timing toward the IRT begins again.

This can be expressed as below (Ferster & Skinner, 1957):

IRT $\geq t \rightarrow$ reinforcement; IRT $< t \rightarrow$ non-reinforcement

The effect of a DRL procedure is to lower the overall rate of some target response by increasing time intervals with responding required between the last target response and reinforcer delivery. It requires the subject not to respond during a specified duration. The subject can respond either at the IRT or above it. If the subject responds before the required IRT is completed, the timer is reset to zero and the reinforcer is withheld. Placing a limited hold (LH) on the DRL can maintain behaviour while at the same time ensuring against excessively long IRT being reinforced (Kelleher, Fry, & Cook, 1959). A LH can assist a subject to focus on the task because it determines a finite amount of time that a reinforcer is available for.

Motivation for reinforcement can influence the behaviour of the subject. A common way of measuring an animal's demand or motivation for a commodity (type of reinforcer) is to examine its performance when responding (Mazur, 1987). Behaviour can be observed to see to what degree it is maintained as the IRT increases. One factor that could change or affect performance is the quality or type of food. In this instance a preference assessment could be carried out to establish a preference hierarchy for the foods (Mazur, 1987). How performance changes can provide a measure of demand for the food. It is generally regarded that satiation and deprivation can affect motivation for a commodity. For example, the greater the food deprivation the more likely the subject will "work harder" (respond more) for a reinforcer. On the other hand, satiation may lower the subjects motivation to “work as hard” (respond less or stop responding) for a reinforcer (Mazur, 1987, Tanno, Kurashima, & Watanabe, 2011). However, in a DRL schedule long time delays are known to affect motivation because responding too early is punished by an increase in time delay to reinforcer consequently resulting in unstable responding (Doughty & Richards, 2002). In contrast to most schedules, quality or type of food bears little influence on the rate of responding on a DRL and thus as a result, deprivation has little effect on DRL responding (Kramer & Rilling, 1970).

As DRL are used to decrease the frequency or duration of a target behaviour, there is much interest in exploring the behaviour that occurs during the IRT (Austin & Bevan, 2011; Handen, Apolito & Seltzer, 1984; Richards, Sabol & Seiden, 1993). This behaviour is often referred to as mediating behaviour or collateral behaviour. Mediating behaviour is behaviour that occurs within the time delay between responses or during an IRT, and denotes a sequenced chain of responses in which each response could function as a discriminative stimulus for a further response (Ferster & Skinner, 1957). Collateral behaviour on the other hand is often referred to as unstable behaviour that cannot be brought under operant control (Kramer & Rilling, 1969). Conversely Laties et al. (1965) and Laties, Weiss and Weiss (1969) argue that collateral behaviour is functional behaviour. They along with Wiley, Compton, and Golden (2000) say that any behaviour maintained during the IRT serves the function of mediating time. Kramer and Rilling (1970) and Kramer and Rilling (1969) distinguish collateral behaviour as behaviour that serves no function although it occurs during the IRT and in contrast argue that mediating behaviour serves a function and can be brought under operant control.

Laties et al. (1965) and Laties et al. (1969) put forward collateral (or adjunctive) behaviour as functional (for example in, Laties et al., 1965, gnawing on a block of wood) when it assists efficient responding. However, it can also be considered functional, when behaviour is interrupted and responding becomes less efficient (as in Laties et al., (1965), removing a block of wood) because interference in behaviour served to prove that a less efficient performance would happen. Interruption of collateral behaviour has advantages in assessing whether behaviour is functional. In Laties et al. (1965) the observed collateral behaviour in a rat of overt tail nibbling end to end, during a multiple schedule DRL and FR experiment, was used to test this theory. The behaviour was interrupted and then re-instated in four different conditions; removal of response lever; an extinction schedule; painting an aversive substance on its tail to discourage nibbling behaviour; administration of amphetamine. With each interruption responding increased and the phase of tail nibbling behaviour decreased. These results suggest that the nibbling behaviour was functional because DRL responding increased when the behaviour was interrupted.

Collateral behaviour and mediating behaviour may both be used as a measurable dependent variable (DV) on DRL schedules (Hodos, Ross & Brady, 1962). In DRL, the IRT can be used as a measure of success for efficiency or as probability at which the IRT occurs (as in Doughty & Richards, 2002). IRT can also be a DV measure, such as, per DRL value (as in the current experiment), or, the mean IRT, or, per session block. Generally, in DRL, as the DRL criterion increases the mean IRT decreases, resulting in decreased efficiency and a decline in obtained reinforcers (Doughty & Richards, 2002).

Collateral behaviour has also been described as a by-product of the DRL procedure (Kramer & Rilling, 1970; Laties et al., 1965; Laties et al., 1969; Skinner, 1938). Although many researchers have concerns regarding the aversive properties proposed in collateral behaviour, it was difficult to locate studies that definitively investigated the behaviour that occurred during the IRT in DRL.

Laties et al. (1965) and Laties et al. (1969), experimental research manipulated collateral behaviour of some subjects in some experiments to assess the degree of collateral behaviour. They reported no adverse effects. In one experiment a block of wood was presented (Laties et al., 1969) and the rat gnawed on the block of wood during the IRT in a prescribed way which accurately discriminated the time delay to obtain reinforcers. To test this further the experimenters (Laties et al., 1969) removed the block of wood and the rat acquired another behaviour of sniffing and licking but was unable to obtain reinforcers anywhere near the level when the block of wood was in the chamber. When the block of wood was returned to the chamber, gnawing quickly resumed and the number of reinforcers obtained increased to the level reached prior to the wood being removed. Laties et al. (1969) stated that the behaviour was notably carried out with "fair precision" (p. 55) and described the behaviour as functional collateral behaviour and furthermore as a 'natural' behaviour of the rat (i.e. gnawing).

In another experiment by Laties et al. (1965), a rat's tail nibbling was observed. The rat moved its mouth from one end of its tail to the other while holding the tail between its paws, appearing to be biting its own tail although no skin was broken and no harm was caused. The behaviour was precise in timing and the direction of the nibbling occurred in a specific way. Reinforcers were obtained efficiently beyond 22-s. The behaviour was considered overt with concerns that the behaviour could potentially cause harm to the animal. There was a noticeable activity of biting however the animals skin remained intact. The behaviour was also described as ‘natural’ because it mimicked the animal’s natural behaviour of cleaning. ‘Species typical’ behaviour of the rat, such as nibbling, licking and gnawing can become dominant adjunctive (collateral) behaviour in experimental studies (as just described in Laties et al., 1965; and Laties et al., 1969). Providing access so that subjects may engage in ‘species typical behaviour’ appeared to contribute to increased efficiency in the above experiments. It also appeared to reduce the likelihood of harm to the animal. Segal (1961) discussed the notion that collateral behaviour on a DRL schedule can effectively improve access to reinforcement.

Collateral behaviour can develop into stereotypic or abnormal repetitive behaviours as a consequence of a chaining of superstitious behaviour when time interval between responses increases (Laties et al., 1965; Laties et al., 1969). These behaviours may develop by previously being adventitiously (accidentally) reinforced. For instance in Laties et al. (1965), the subject’s overt behaviour of tail nibbling could be viewed as stereotypic because of the self-stimulatory and repetitive body movements the subject displays as a consequence of a chaining of behaviours. Such a topography of chaining behaviours can inadvertently be harmful to the subject (Anger, 1963) although in the above described experiment, that was not the case. Anger (1963) suggested that the only way to clearly determine the functional role of collateral behaviour may be to systematically manipulate them then observe the effects on the acquisition of temporal discriminations. Laties et al. (1965) and Laties et al. (1969) carried out their experiments with this in mind and were able to report on the functional role of the collateral behaviour observed. Furthermore, they were able to provide access for some of the subjects to engage in 'species typical behaviour' which contributed to an increase in efficiency and no adverse effects on the subjects.

Studies on timing with animals has been widely investigated (Doughty & Richards, 2002; Kramer & Rilling, 1969; Kramer & Rilling, 1970; Laties et al., 1965; Laties et al., 1969; Lejeune, Richelle, & Wearden, 2006; Orduna, et al., 2009; Rescorla, 1967; Richards et al., 1993; Singh, Dawson, & Manning, 1981). Doughty and Richards (2002) suggest that animals do not have the capability to discern time particularly when it comes to long time delays. They suggest that other stimuli in the animals repertoire influences response rates and can induce arousal. In their study using rats and pigeons they wanted to test DRL performance on a longer time delay by increasing reinforcer magnitude. It was predicted that on DRL schedules, increasing reinforcer magnitude in longer IRT would result in stable responding. This was not the case; they found that larger reinforcer magnitudes consistently produced bursts of responding immediately after delivery. They noticed also that the longer the passage of time, and the greater the magnitude of the reinforcer, the greater the arousal, and an increase in unstable responses. Doughty and Richards (2002) suggest that the larger quantity reinforcer coupled with the longer time delay acted as extra stimuli that directly affected arousal resulting in unstable conditioned responses. Withholding access to food resulted in response bursts that occurred at a high rate and continued despite the subject's unstable responses.

Anger (1963) stated that an animal could develop temporal discriminations capably over a course of time. In the animal studies researched, the DRL schedules produced results that support Anger's (1963) findings. For example, Laties et al. (1965) mouse's adventitious or collateral behaviour could be viewed as the animal capably discriminating time intervals by using precise behavioural responses that mediate the specific time to reinforcement. Kramer and Rilling (1970) state that animals will withhold responding if time delays from response to reinforcer are too spaced out indicating that the animal may be capably discerning that the time gap is too long. The displays of overt mediating behaviour are a move away from the notion that some kind of internal clock within the animal functions the behaviour (Fraisse, 1963). Thus the studies support the notion that when a concurrent behaviour is made available the animal will likely engage in it as a discernible way to mediate the space of time to reinforcer delivery. Laties et al. (1969), Wiley et al. (2000) and Doughty and Richards (2002) do not believe that animals are able to discriminate time and argue that collateral behaviour once brought under operant control functions to allow animals to mitigate time. Laties et al. (1969) further argues that interrupting responding in a rats' adjunctive behaviour of gnawing wood by removing the block of wood, would not have occurred if there were an internal timing process. In addition, they argue that collateral behaviour can be considered functional if interference such as the removal of the block of wood, results in less efficient responding. Fraisse (1963) queries whether schedules such as these really require an explicit timing or sense of time on the part of the animal when collateral behaviour is brought under operant control and it is that particular mediating behaviour that discriminates time to reinforcer. Furthermore, collateral behaviour may alleviate the problem the animals have of not having an internal timing mechanism (Wiley et al., 2000). In contrast, Anger (1963) argues that animals do indeed have an internal timing mechanism thus giving them the ability to perform temporal discriminations. For example in the same way as people might improve their timing using an external clock, an animal might mediate time with an internal mechanism that is assisted by external cues, such as lights, sounds or movements.

Some studies of DRL do not focus on collateral behaviour. Anger (1963) did not observe evidence of collateral behaviour and thus made the assumption that animals can actively inhibit their responses because they possess an internal timing mechanism that assists them to perform temporal discrimination. Wiley et al. (2000) suggested that premature responding is a result of the animal not having an internal timing mechanism and being incapable of inhibiting their responses and thus inefficient responding is an adjunct of this.

It was difficult to find studies that parametrically investigated DRL (as in the current study). Many studies of DRL do not increment the DRL value parametrically but instead may have two or three different parameters (Browne, 1979; Deitz, 1977; Deitz & Repp, 1973; Doughty & Richards, 2002). For example in Doughty and Richards (2002) a two-phase DRL experiment was conducted with a 72-s in the first phase and an 18-s in the second phase with alternating reinforcer magnitude in both phases. The larger reinforcers were found to result in less differentiated IRT which were unstable and not often accurate.

DRL schedules require that responses be separated by an amount of time (Skinner 1938) and thus DRL schedules are in principle timing schedules. DRL can be arranged into three different types of schedules: *Full session DRL, Spaced Responding DRL* and *Interval DRL* (Austin & Bevan, 2011; Kramer & Rilling, 1970). Many researchers describe DRL as a positive intermediary when dealing with problematic or disruptive behaviour in children, as opposed to the more traditional forms of physical punishment and harsh verbal discipline (Austin & Bevan, 2011; Deitz, 1977; Deitz & Repp, 1973; Deitz, Slack, Schwarzmueller, Wilander, Weatherly, & Hilliard, 1978; Kramer & Rilling, 1970; Lennox, Miltenberger, & Donnelly, 1987; Singh et al., 1981). There are many studies of DRL in applied settings that measure how to inhibit high functioning and problematic behaviour of children. Austin and Bevan (2011) described how a full session DRL was effective in reducing excessive rates of requesting teacher attention by three young girls in a classroom situation by reinforcing only the good behaviour at the end of the session.

A full session DRL spans an entire session and involves reinforcing an average rate of responding if response or behaviour is emitted less than or equal to a pre-determined number (Browne, 1979; Deitz, 1977; Deitz & Repp, 1973). The delivery of a reinforcer occurs after the session has ceased. Spaced-responding DRL is where reinforcement is delivered when a response or behaviour occurs at the end of, or follows the previous response by a fixed minimum amount of time (Deitz, 1977). If a response occurs before the IRT has elapsed reinforcement is withheld, timing stops and reset from that point. A full session DRL was also successful in the reduction of inappropriate questioning by behaviourally disturbed children in Deitz (1977) Experiment II, by reinforcing only when inappropriate questioning did not occur. Of particular interest was Deitz and Repp's (1973) study where they treated three widely divergent groups; a trainable mentally retarded (TMR) boy, a special classroom of ten TMR students and a regular high school business class of fifteen teenage females. Classroom misbehaviour across the three subject groups decreased when only good behaviour was reinforced and the problematic behaviour was ignored. The researcher's results proved the efficacy of full session DRL across the diverse groups. This study also demonstrated another feature of DRL (also in Deitz, (1977) Experiment III) and that is that it could eliminate a target behaviour simply by increasing DRL limits in successive steps until the behaviour is extinguished. In Lennox et al. (1987) full session DRL effectively reduced rapid eating in three mentally retarded adults by increasing the DRL criterion in small successive steps until eating was at a slower and more manageable rate. Overall, full session DRL schedules were effective in reducing the rates of disruptive behaviours targeted across the diverse populations described. Verbal cues (such as alerting the participants to the time remaining in the session) and physical cues (such as directing hand movements away from food until time delay lapsed) were features in the above experiments, assisting the participants to navigate the schedules.

Spaced-responding DRL typically shows an increase in IRT and a decrease in rate of responding. This schedule is more commonly used within laboratory settings to assess responding by manipulating specific variables (Dietz, 1977). When DRL value is increased in larger increments across time a reduction in the frequency of a target response or behaviour is the proposed outcome (Austin & Bevan, 2011). Spaced responding DRL has been used across diverse populations to reduce the rate of a problem or disruptive behaviour. Singh et al. (1981) reduced stereotypy in profound developmentally disabled persons. The schedule effectively reduced stereotypic responding by increasing IRT in larger increments. At the same time appropriate behaviour increased. Deitz (1977) successfully reduced inappropriate questioning (Experiment I) by using spaced responding DRL schedules on children with behavioural disorders.

Interval DRL is similar to spaced responding DRL. Interval DRL operates by separating responses with a specific time interval. The reinforcer is delivered only when the response has occurred after the specified IRT (Browne, 1979; Deitz, 1977; Deitz & Repp, 1973). If a response occurs before the specified IRT, the wait period is reset to zero and reinforcer is withheld. An interval DRL should typically show a decrease in the target behaviour as the IRT increases. This schedule can also be successfully used with human subjects in applied settings particularly where disruptive or problematic behaviour are an issue (Brown, 1979; Deitz, 1977). During the span of time between intervals, behaviours or responses may occur that are outside of the target behaviour. More commonly, these behaviour have been described as collateral or adjunctive behaviours (Kramer & Rilling, 1970; Laties et al., 1965). The time delay from response to reinforcer has been suggested as a reason for the adjunctive behaviour occurring. These behaviour help the organism fill the IRT with other than the operant response when early responses that did not fulfil the DRL requirement were not reinforced (Kramer & Rilling, 1970; Laties, et al., 1965).

Interval DRL schedules can also effectively reduce a range of problem behaviours. In Deitz (Exp. III, 1977), and Deitz et al. (1978) the effectiveness of interval DRL schedules were reported with a range of problem behaviors in children with special needs. Included in these behaviours were inappropriate talk-outs, aggressive and inappropriate behaviour, failing to raise one's hand before speaking and property destruction. In each of the studies, the children were informed by the teachers of the maximum number of responses that they could make within each interval (consisting of around 2 to 5 minutes). Reinforcers or rewards were delivered contingent on meeting the criterion for a particular number of intervals. In each of these studies the inappropriate behaviour reduced and were maintained over 6 month and 14 month follow ups. Handen et al. (1984) used a similar procedure to reduce repetitive speech in an autistic adolescent. Using a reversal design and tokens as reinforcers for emitting fewer than the target number of repetitions per interval, the behaviour was reduced and maintained over 6 month and 14 month follow ups.

Interval and full session DRL are more appropriate within applied settings (Austin & Bevan, 2011; Browne, 1979). These schedules are better suited because they do not require as much time or attention compared to space responding DRL (Austin & Bevan, 2011). Full session DRL schedules have been used widely to reduce rates of problem or disruptive behaviour across diverse groups with varied response topographies.

Overall, these studies suggest that DRL arrangements can offer effective alternative methods in the applied setting to reduce problem behaviour across divergent populations of people. Keeping the schedule simple can also ensure an uncomplicated intervention. Thus, it is suggested that these schedules are not just suited to experimental studies. The examples of interval DRL and spaced responding DRL in the applied setting show the schedules suitability with human subjects (Brown, 1979; Deitz, 1977). However, it is noted that the applied DRL studies described showed competing parameters at work by the experimenters during the sessions. For example the experimenters were instructing the participants what to do, instructing them when time was nearly up, instructing a minimum number of behaviours to illicit during an experimental session and physically cuing participants. The parameters described mimic two other schedules of behaviour DRO (differential reinforcement of other behaviour) and the DRA (differential reinforcement of alternative behaviour). DRL has often been associated with DRA and DRO, however, these schedules will not be discussed in this thesis as they are not the subject of this study.

In the present study, possums' ability to perform on a DRL will be investigated. The animals will be recorded on a digital camera in an attempt to see if the animals made use of any obvious adjunctive behaviours that may have mediated their DRL performance. This will only be observed in a small way as it is outside the scope of this study to report on. In Experiment 2, a second lever will be provided to see if animals might naturally develop a mediating behaviour of pressing the second lever as a way of improving their DRL performance.

It is proposed that the possums would perform reliably on the DRL schedule in Experiment 1. It is further proposed that the possums would utilise the second lever in Experiment 2 to improve DRL performance.

Method

Subjects

The subjects were six Brush tail possums (*Trichosurus vulpecula)*, labeled A1 through to A6. At the beginning of the experiment, three possums were experimentally naïve (A1 Kayla, A3 Joey and A4 Lily) and three had previously participated in experimental studies on sequence learning (A2 Gus, A5 Baxter and A6 Lily). The possums were housed individually in cages. The rooms in which the possums were housed were maintained on a 12:12 hour reversed light/dark cycle. Experimental sessions occurred during normal daylight hours, which were in the possum's dark rotation with minimal illumination supplied by two 60-watt red lamps.

The possums were fed a supplementary diet of commercial possum pellets in the mornings and apple or carrot and dock leaf *(Rumex obtusifolius)* at least one hour following the conclusion of an experimental session. Post feed of possum pellets was provided at the completion of each experimental session and the amount was dependent on the number of reinforcers obtained during the experiment and the individual possum's weight. Fresh water was available at all times. Each subject was weighed once a week and its body weight was maintained at a previously determined value, which motivated him or her to respond. Feed was increased or decreased to maintain weight. The University of Waikato Animal Ethics Committee approved this research (Protocol number 902).

The sex, approximate age and target weight for each subject are presented in Table 1.

Table 1:

Name, sex, age and target weight of each subject

	Sex	Approximate age	Target Weight (grams)
A1 Kayla	F	4	3720
A2 Gus	M	9	3738
A3 Joey	M	3	3450
A4 Lily	F	4	3680
A5 Baxter	M	9	3859
A6 Dusti	F	6	3468

Apparatus

The possums were housed in individual cages. Each cage functioned as the experimental chamber and 'home cage'. Normally there was a physical barrier between the animal cages. A4 was born in captivity to A3. A4 and A3 had visual access to each other through the grid walls. A1, A2, A5 and A6 had steel sheets placed on the sides of their cages, which blocked visual access to another possum. The laboratory room operated on a reverse 12:12 hour light/dark cycle. Three 60-watt red light bulbs provided minimal light during the dark cycle. These lights functioned to allow visibility for researchers with minimal disturbance to the animals. Each possum's home cage (550-mm wide, 1000-mm high, and 580-mm deep) consisted of metal grid sides, floor and roof with a wooden nesting box (450-mm wide, height sloping from 360 mm to 190 mm, with a depth of 300 mm) on top of the roof of the cage that the possums had constant access to.

The response panels were mounted on the outer side of the cage door and measured 110-mm wide by 230-mm high. Food dispensers allowed timed access to a mix of coco pops and barley. Two vertical slots were cut into the panel for the two switches. The switches were a micro-switch Honeywell BZ-2RW863/A2 with a 15 mm "activator" and levers were made of light steel. Immediately above the left and right levers were yellow LED lights that indicated when the schedules of reinforcement were in effect. A force of 0.2 n was required for lever press to activate the switch. The magazine allowed 3-s access to the reinforcer (pellets) following a correct response. The programme used to record data and control the events of the experimental equipment was MED-PC.

Pre-training

Each naïve possum was trained to press a lever. The possums then received three or four consecutive training sessions on a CRF (continuous reinforcement) schedule of reinforcement. Each CRF session either took an hour or stopped after 100 reinforcers were obtained. When the possums were able to get 100 reinforcers over two consecutive days the pre-training ended.

Procedure

Daily experimental sessions were conducted during the dark cycle, beginning between 9.30am and 10.30am. Experimental sessions lasted for 3600-s, or until 100 reinforcers were consumed, whichever occurred first. The criteria for ending the experiment for each possum was two consecutive experimental sessions of no responding. Two Experiments were conducted.

Experiment 1.

Experiment 1 involved one lever on a DRL schedule. The DRL value started at 0.20-s and incremented by 20% after no less than 300 reinforcers were reached for each value. An experimental session ended when 3600-s or 100 reinforcements were obtained, which ever occurred first. If lever press occurred before the specific IRT then the DRL count was reset to zero and timing started again. When responding ceased for two consecutive experimental sessions it signaled the end of the condition.

Experiment 2.

Experiment 2 involved two levers – one DRL lever on the left hand side, with reinforcer and a second lever on the right hand side with no reinforcer. The right hand lever was simply present during the duration of the experiment and responses to it were recorded but were not reinforced. The DRL value began at 1.03-s. This value was determined after the first experiment established that possums could perform 95-100% accuracy at 1.03-s. The DRL value incremented by 20% after no less than 300 reinforcers were reached for each value. An experimental session ended when 3600-s or 100 reinforcements were obtained, which ever occurred first. If lever press occurred before the specific IRT then the DRL count was reset to zero and timing started again. When responding ceased for two consecutive experimental sessions it signaled the end of the condition.

Results

Figure 1 represents the percent reinforcement or the efficiency ratio for all six possums across both experiments. The Y-axis shows the mean percent correct responses against incremental DRL conditions. The X-axis shows the DRL conditions incremented in seconds. Experiment 1 is represented on the graph with a line and open circles. Experiment 2 is represented on the graph with a line and crossed circle. For each DRL condition, the percentage rate of reinforcement was calculated. These values were then arranged across the three (or more) sessions that it took before incrementing to the next DRL criterion, or the time that it took for the possum to extinguish behaviour. The data showed a constant rate of responding of 90 percent to 100 percent across all possums until around DRL condition of 15-s where there was a quick decline to around 40 percent, a flattening, then a further quick decline of below 20 percent with some variability amongst the possums after that.

Figure 2 shows efficiency ratio against logged DRL to better illustrate the function of low response rates across both experiments. The Y-axis shows the mean reinforced responses in percentages (percent correct) for each DRL condition. The X-axis shows the DRL conditions logged. Experiment 1 is represented on the graph with a line and open circles. Experiment 2 is represented on the graph with a line and crossed circle.

The data clearly illustrates a deterioration in performance as DRL increases with the decline evident across all possums. *Figure 2* further illustrates the possums' poor performance on a DRL schedule of behaviour and is consistent with *Figure 1*, illustrating more clearly the shape of the drop in performance.

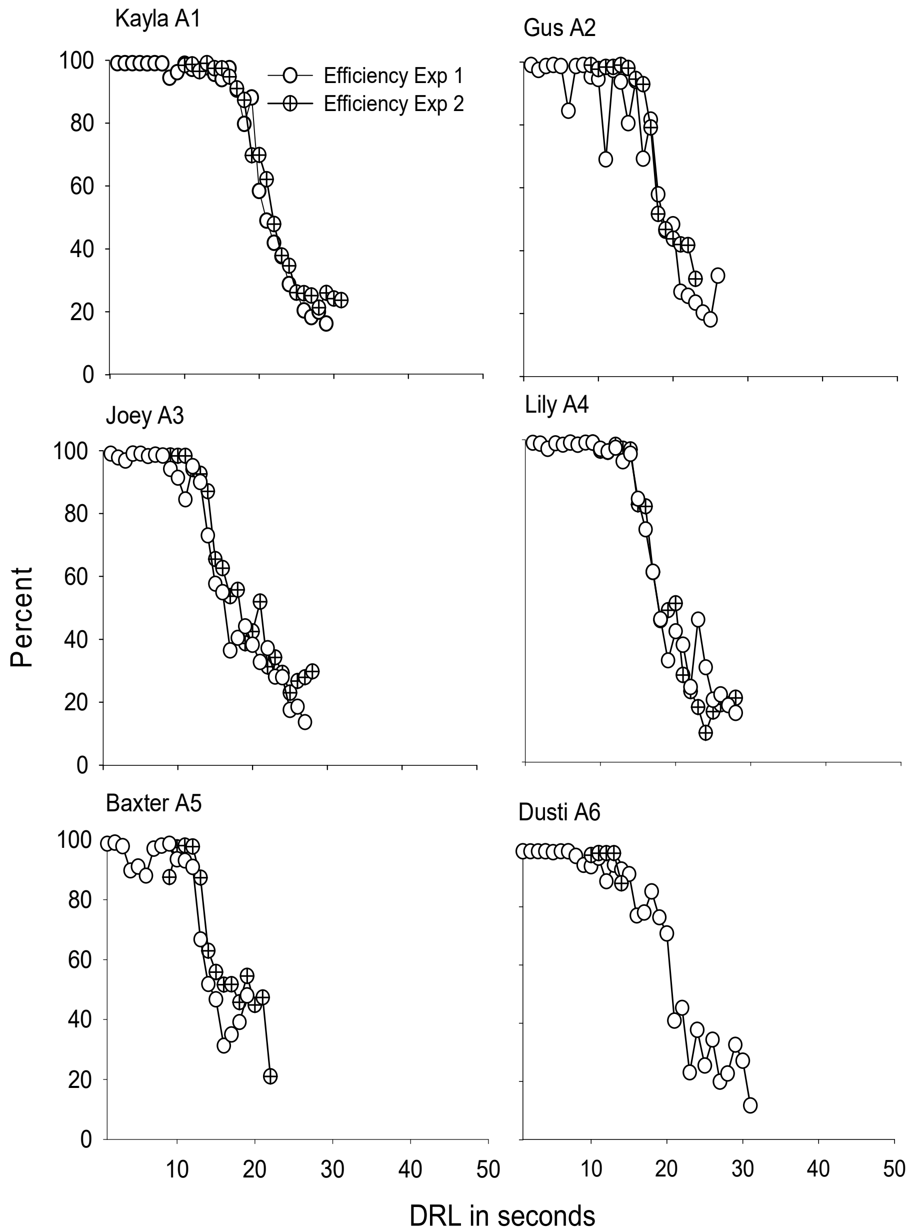

Figure 1. Efficiency ratio calculated by dividing the total number of reinforced responses by the total number of responses at the end of each DRL trial at each DRL requirement.

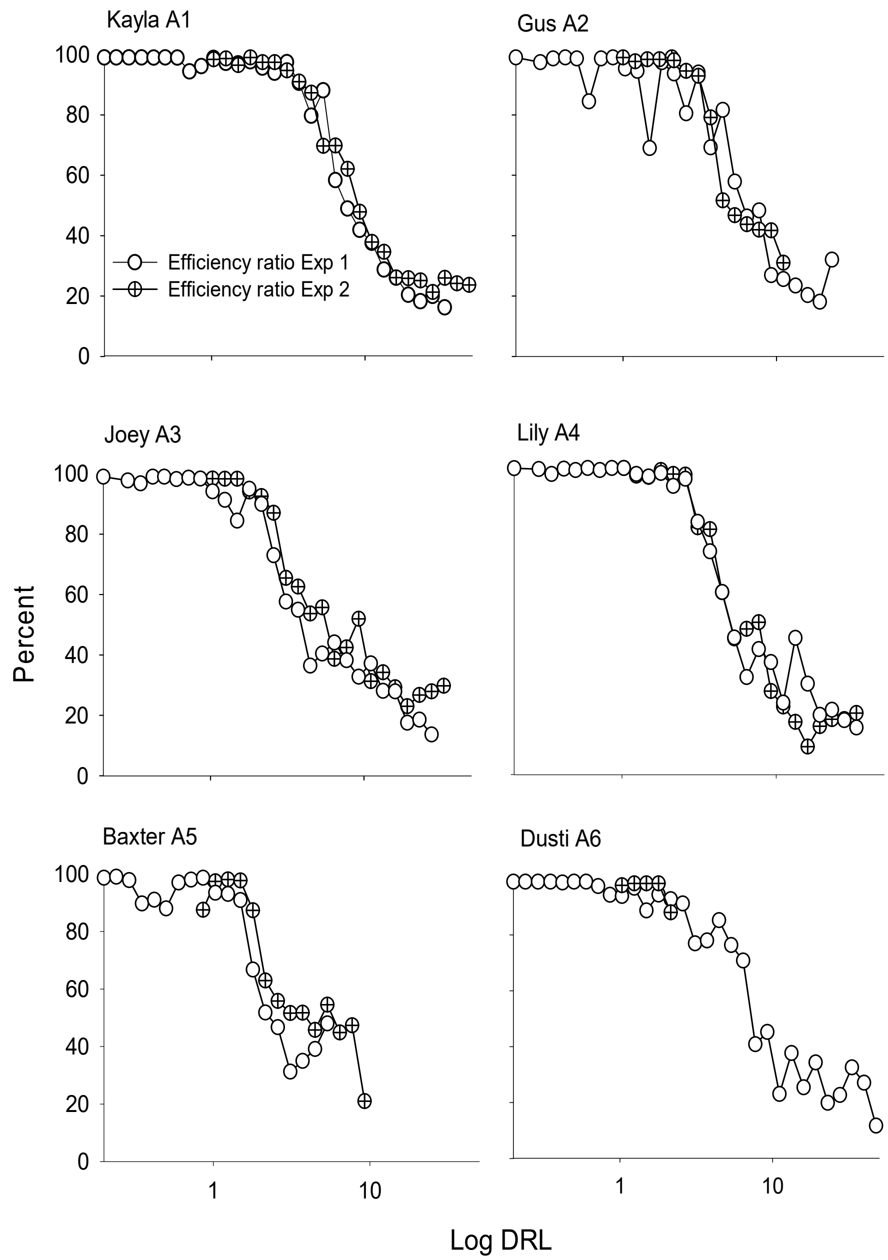

Figure 2. Efficiency ratio measured across logged DRL to provide a clearer view of possum performance at the beginning and end of the experiment.

Figure 3 presents the average IRT distributions across all six possums in both experiments. The Y-axis shows the average IRT in seconds against incremental DRL conditions. The X-axis shows the DRL conditions incremented in seconds. Experiment 1 is represented on the graph with a line and open circles. Experiment 2 is represented on the graph with a line and crossed circle. The DRL values are represented on the graph with a black curved line. The graph shows the possum's gradual performance decreasing as IRT increases. The possum's performance is plotted against the curve of the DRL.

In Experiment 1 initial training on the DRL with small incremental shifts shows IRT did not exceed the criterion across all possums until around 10-15-s with Dusti maintaining performance until around 20-s. Joey and Baxter show unreliable data with both possums showing IRT in excess of 50-s with some of Baxter's IRT exceeding 200-s. The subject's actual performance appeared to be following the predicted DRL performance. Experiment 2 shows that Kayla, Gus, Joey and Lily did not exceed the criterion until around 18-20-s. Baxter showed no reliable pattern of behaviour in responding and Dusti extinguished behaviour after only three trials.

In *Figure 4,* the possum's performance across IRT against a logged DRL is presented enabling a closer inspection of the IRT variation. The graph indicates a decline in performance across all possums and across both experiments at around 10 – 20-s with a noticeable cluster under the DRL criterion from then on. Baxter's unreliable pattern of responding and extreme values suggest that Baxter ceased responding for long periods. Joey's somewhat poor pattern of responding in Experiment 1 is noticeable; therefore, some of the data points should be ignored. For the majority of the possums performance at lower DRL appears consistent, and at higher DRL performance appears unstable and poor.

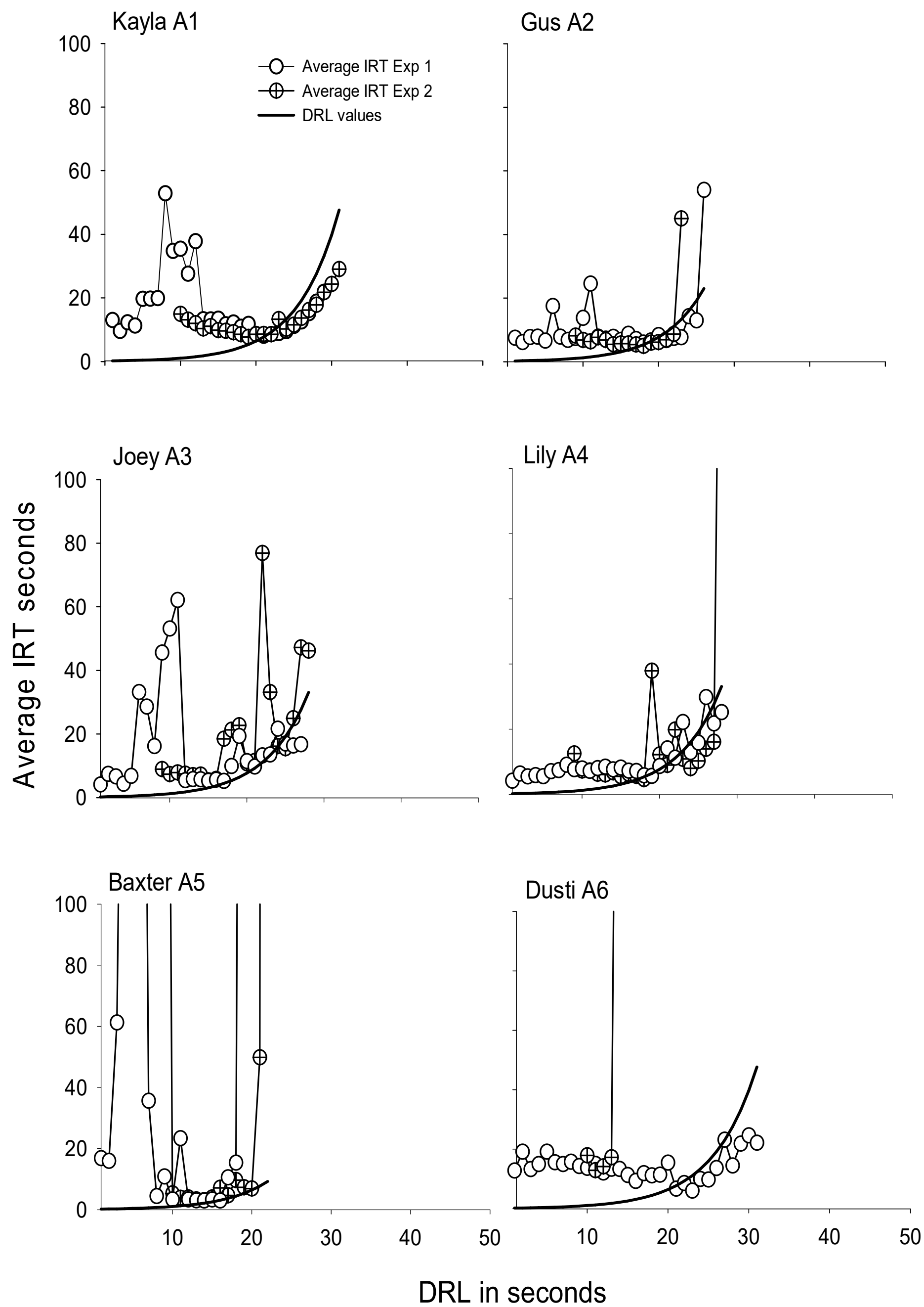

Figure 3. Mean IRT showing possums response rates across both experiments.

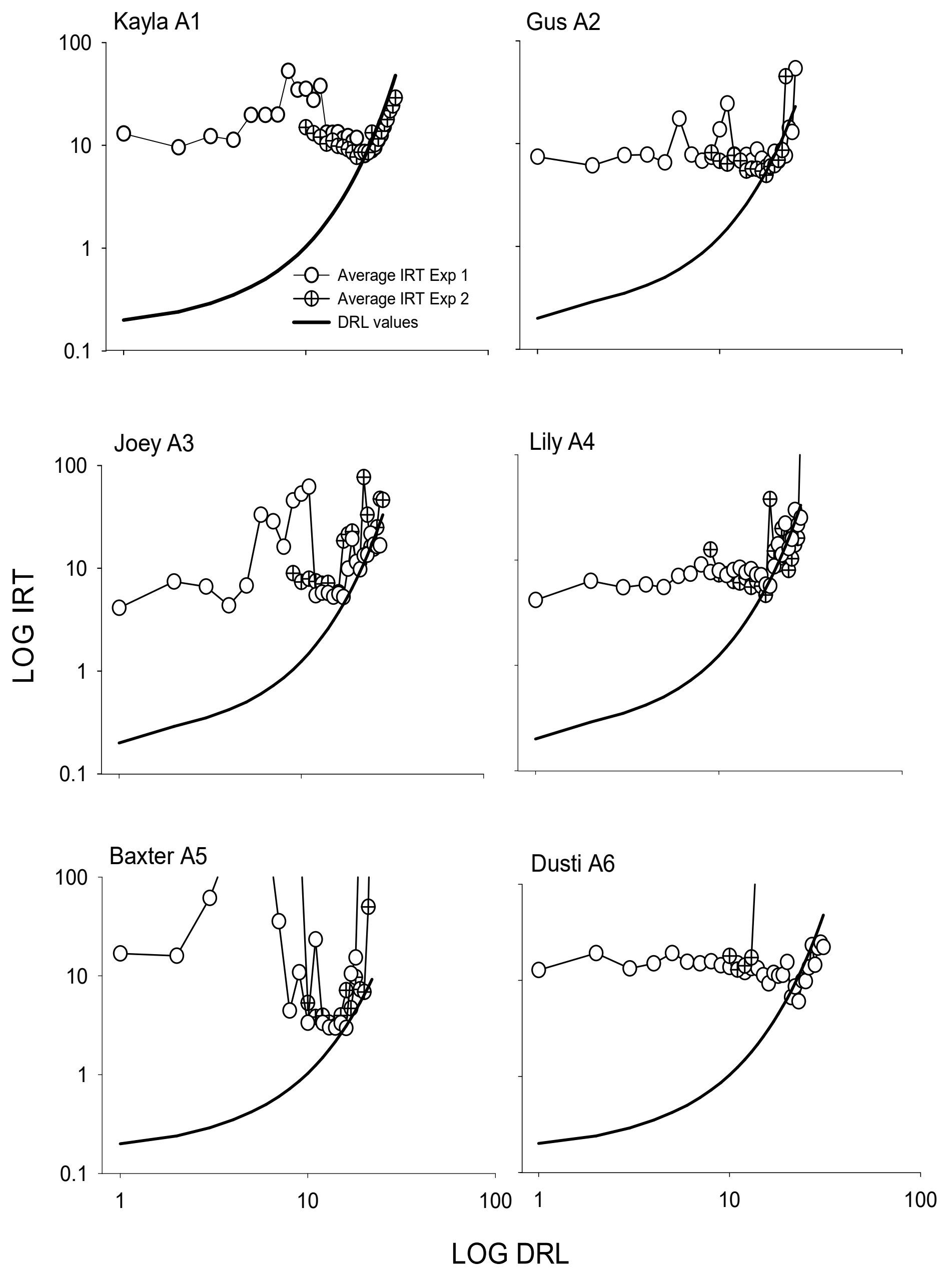

Figure 4. Log mean IRT showing response rates across both experiments.

Figure 5 represents average successful IRT for all six possums across both experiments. The Y-axis shows the average successful IRT in seconds against incremental DRL conditions. The X-axis shows the DRL conditions incremented in seconds showing the possums performance measured against slope of DRL.

Experiment 1 is represented on the graph with a line and open circles. Experiment 2 is represented on the graph with a line and crossed circle. The DRL values are represented on the graph with a black sloping line. The data shows that in Experiment 1 and 2 all six possums maintained performance above the DRL line suggesting that the possums successfully met the DRL requirement. The data suggests good performance when the data is compared to the DRL reference line.

Figure 6 represents the logged version of average successful IRT for all six possums across both experiments. This graph clearly shows all possums rate of responding began well above the DRL line and remains constant until around 15 – 20-s. As the curve of the DRL line inclines, responding becomes closely grouped. The graph suggests that the possums were able to meet DRL requirement across both experiments.

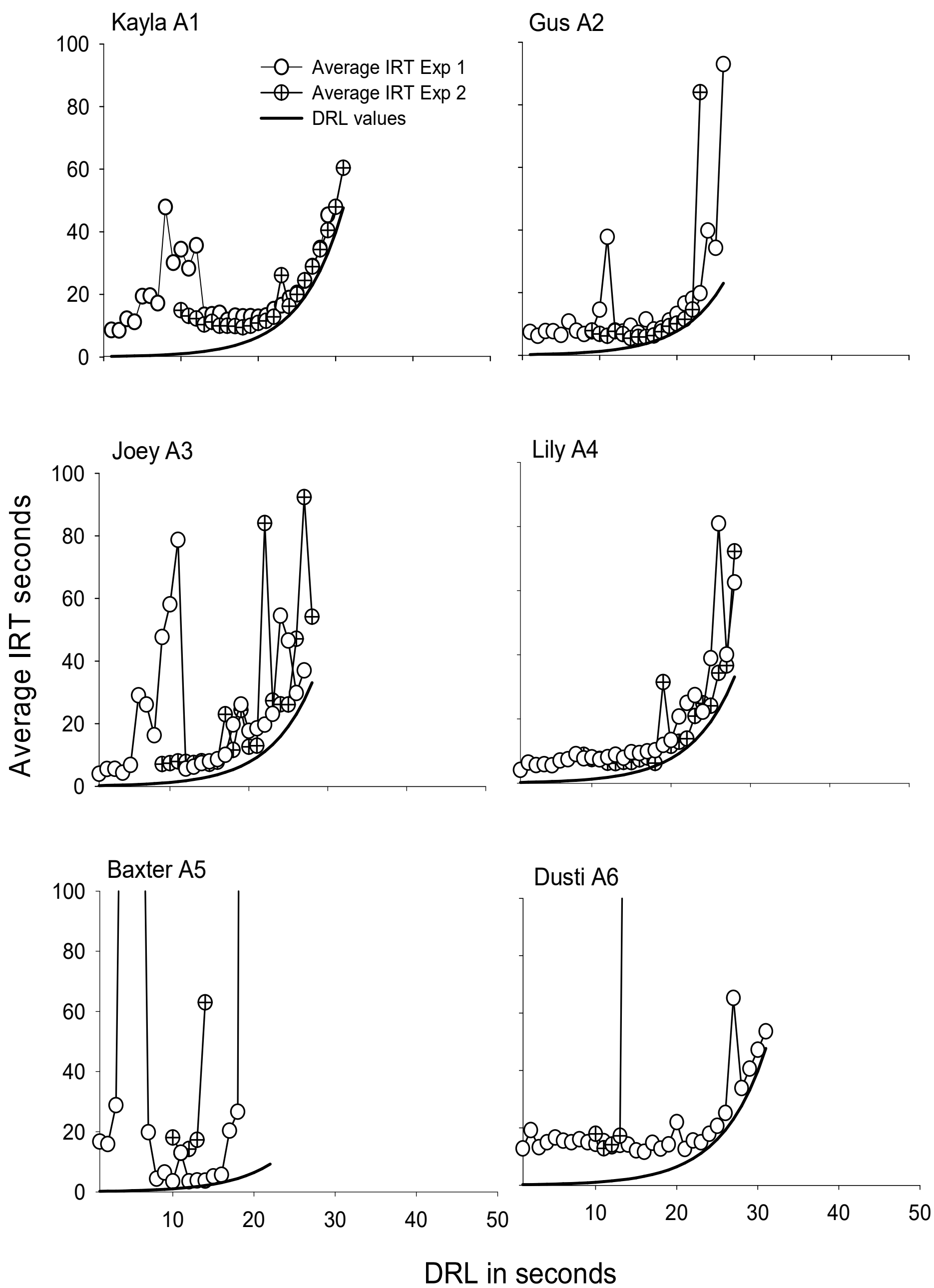

Figure 5. Mean successful IRT across DRL values in both experiments.

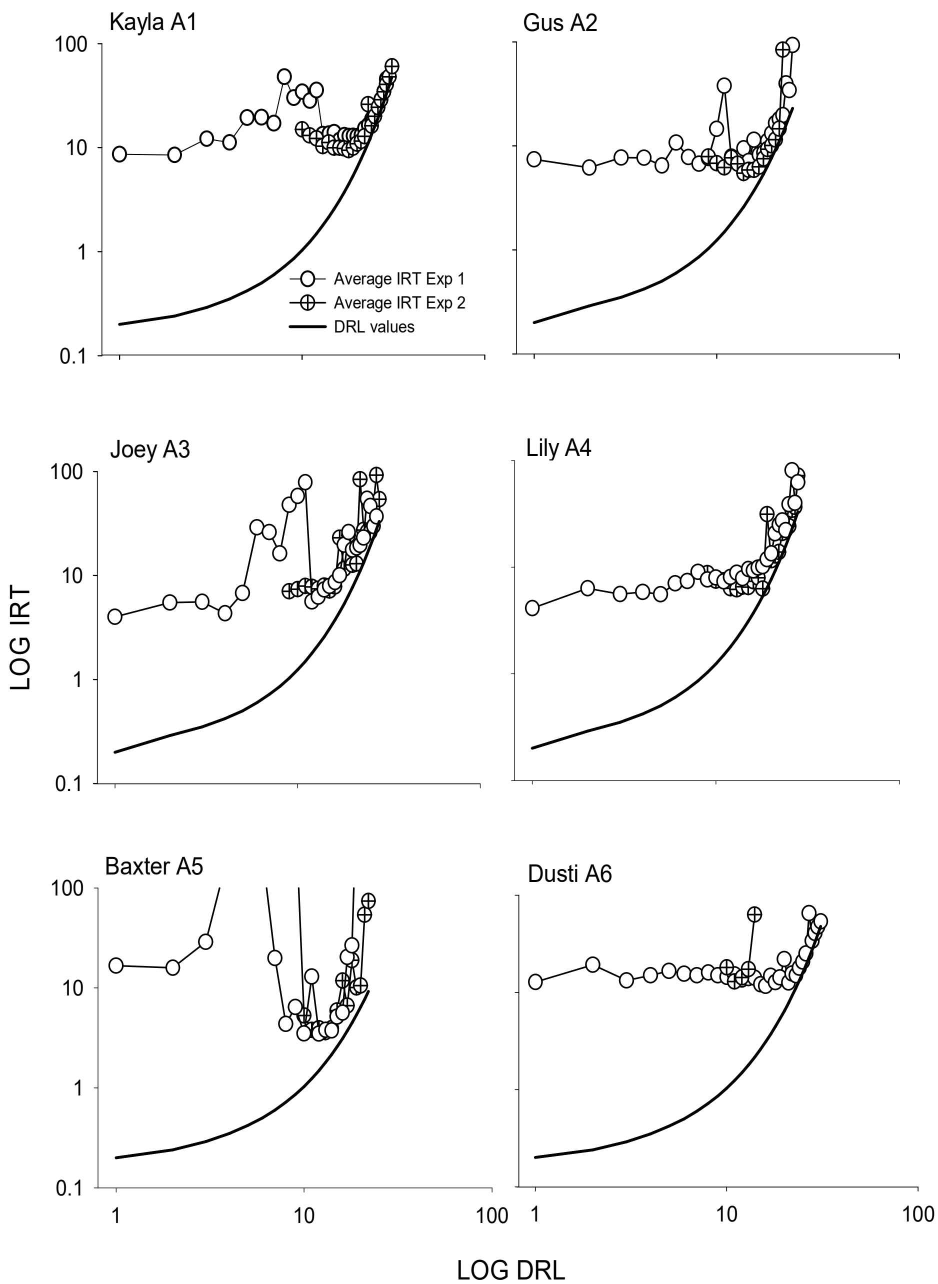

Figure 6. Log mean successful IRT across both experiments to show possums low rate performance against slope of logged DRL.

Figure 7 represents response rates of all six possums across both experiments on left hand and right hand levers. The Y-axis shows mean responses per second. The X-axis shows the DRL conditions incremented in seconds. Experiment 1 LH lever is represented on the graph with a line and open circles. Experiment 2 LH lever is represented on the graph with a line and crossed circle. Experiment 2 RH lever is represented on the graph with a line and black circle.

The data showed a constant rate of responding then an increase in responding followed by a spike in responding as DRL increases, followed by a decline. Lily showed a gradual decline without a spike in Experiment 2. Overall possums responding on the RH lever in Experiment 2 was low.

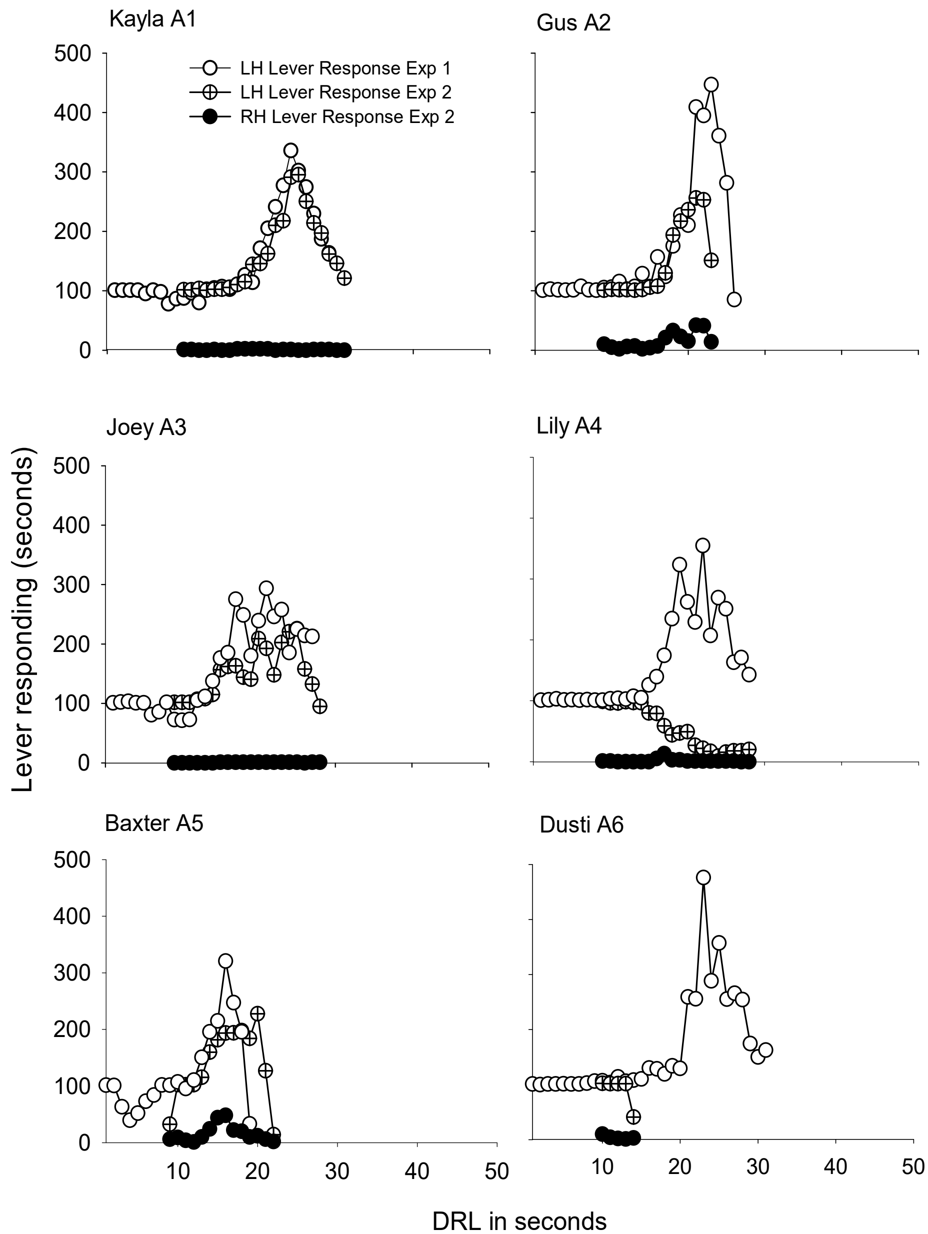

Figure 7. Mean response rates across Experiment 1 and 2 on left-hand (LH) lever, and, Experiment 2 right hand (RH) lever mean response rates.

Figure 8 represents the percent reinforcement or the efficiency ratio for all six possums across both experiments. The Y-axis shows the mean percent correct responses against incremental DRL conditions. The X-axis shows the DRL conditions incremented in seconds. Experiment 1 is represented on the graph with a line and open circles. Experiment 2 is represented on the graph with a line and crossed circle.

For each DRL value, the percentage rate of reinforcement was calculated. These values were then arranged across the three (or more) sessions that it took before incrementing to the next DRL value or sessions that it took the possum to extinguish behaviour.

The data showed a constant rate of responding at 90 percent to 100 percent across all possums until around DRL value 15-s where there was a quick decline to around 40 percent, a flattening, then a further quick decline of below 20 percent with some variability amongst the possums after that. The data suggests poor performance when the data is compared to the DRL reference line.

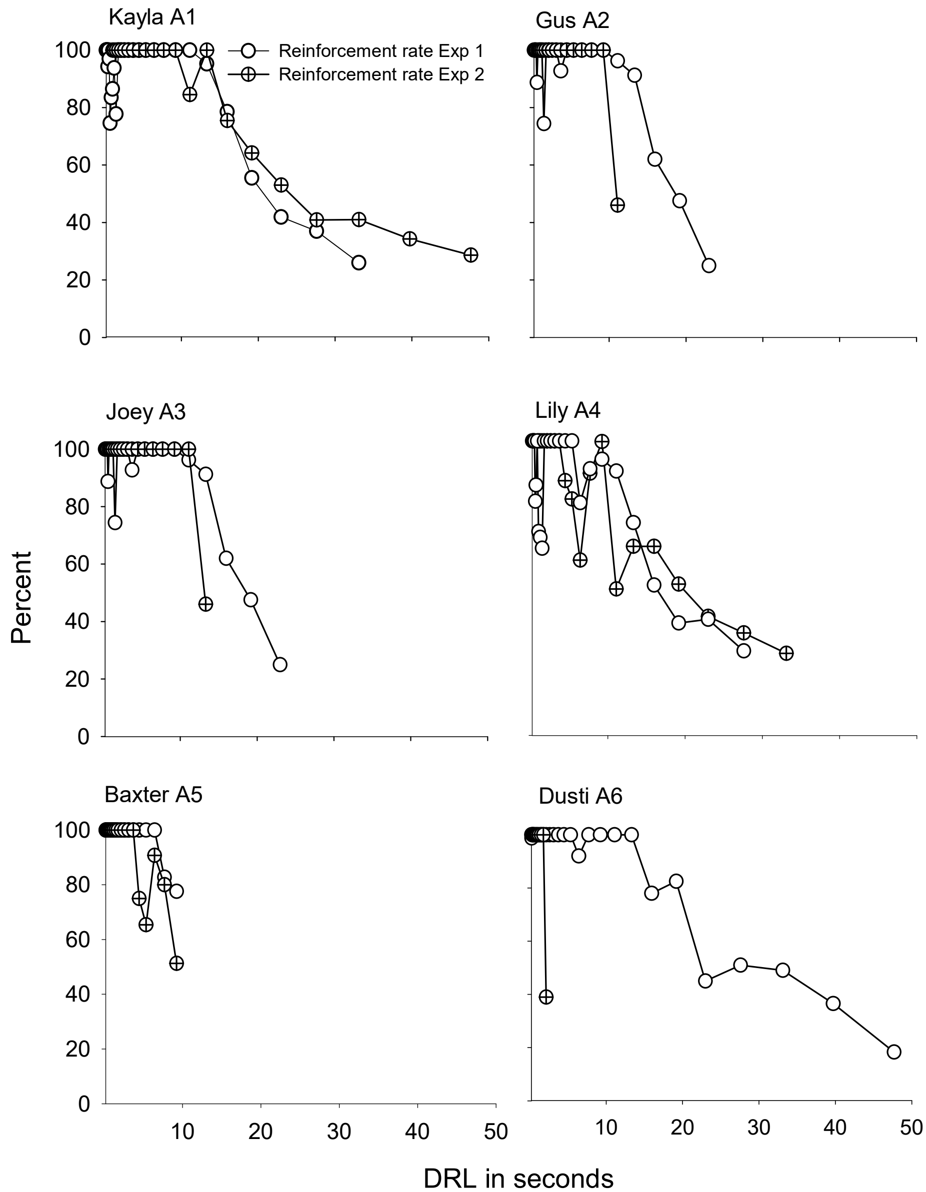

Figure 8. Average reinforcement rates expressed in percentages averaged over the number of days it took for possums to reach DRL criterion for each DRL trial.

Figure 9 represents the number of days it took to complete each DRL value for all six possums across both experiments. The *Y-axis* shows the number of days and the *X*-axis shows the DRL values incremented in seconds. Experiment 1 is represented on the graph with a line and open circles. Experiment 2 is represented on the graph with a line and crossed circle. The data clearly shows that as the DRL value increased the number of days to complete the DRL increased.

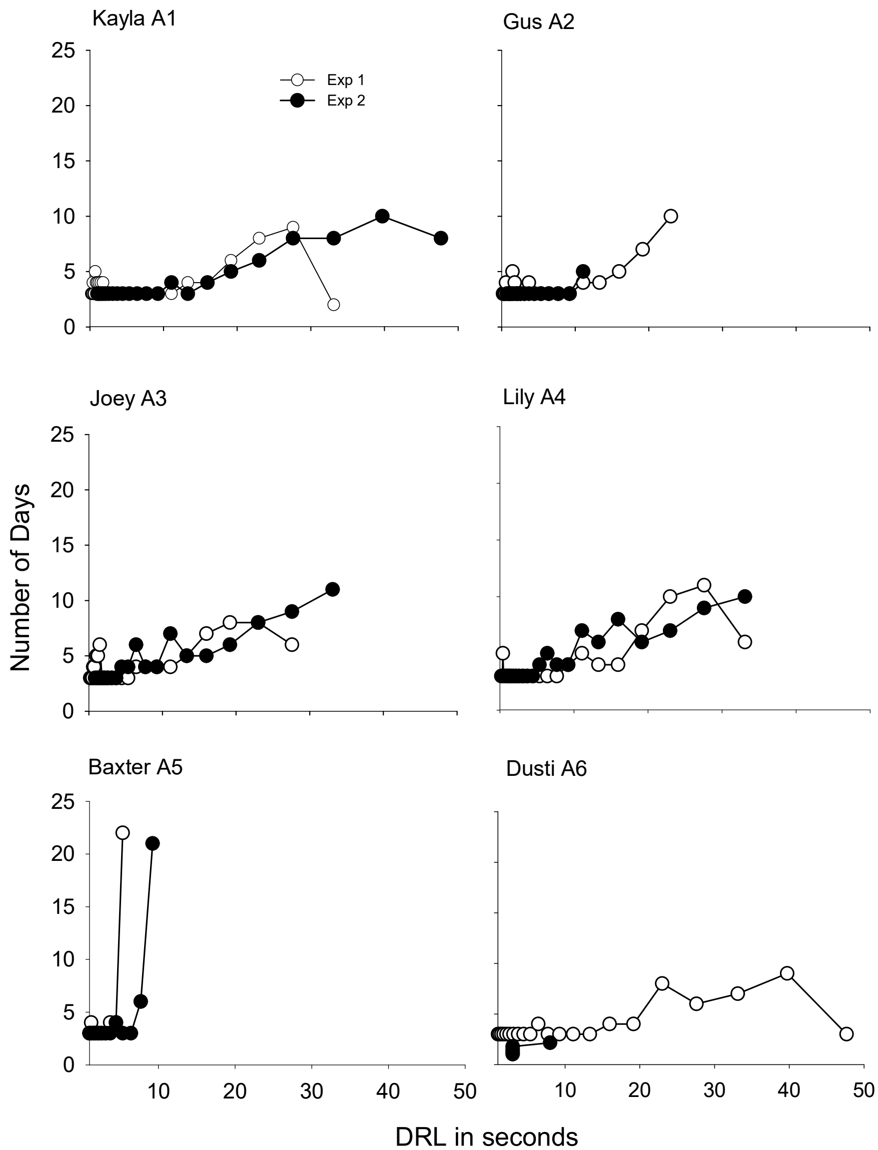

Figure 9. Number of days it took for each possum to reach DRL criterion at each DRL value.

Discussion

This thesis had two experiments. The first experiment investigated the ability of possums to perform on a DRL schedule, with the schedule incrementing from DRL (0.20-s) to DRL (30-s or larger). This may be the first time DRL schedules have been investigated parametrically. The second experiment introduced an ineffective second response lever and this familiar manipulanda gave the possums an opportunity to mediate temporal discrimination and improve DRL performance.

The DRL data in Experiment 1 and Experiment 2 gave the appearance that possums could successfully perform on a DRL schedule with the exception of Baxter who could not maintain performance beyond 5secs in Experiment 1 and 10secs in Experiment 2. For the other possum's performance remained constant up to around 20-s in Experiment 1. The data mimicked a typical DRL schedule whereby response rates increased as IRT increased, with a resultant rapid decline in efficiency ratios (see *Figure 1*) and reinforcement rates (see *Figure 8*). In Experiment 1, most of the possums went beyond 22-s with Dusti going out to 47-s. Dusti's performance was unexpected as it is often argued that animals are unable to reach high DRL without an explicit alternative behaviour to facilitate performance (e.g. Laties, et al., 1965; Laties, et al., 1969). Furthermore, greater value is often given to shorter IRT because of the immediate expected reward (as in Mazur, 1987; Doughty & Richards, 2002) and that as delay to reinforcer increases, the value of that reinforcer decreases.

Ad-hoc videos were recorded but they were not analysed in any detail. Nevertheless, some observations were made of Dusti at the higher DRL, which revealed the subject going around and around in circles a number of times followed by standing in the back corners and sniffing, then resting a paw on the lever before lever pressing. From other observations during the time delays, a similar pattern was regularly detected. Observations of Baxter revealed the subject was often observed off the floor and in its nesting box during the experimental procedure. Sometimes Baxter would return to the floor and lever press obtaining a reinforcer and then return again to its nesting box for long periods of time. Joey was sometimes observed in the nesting box during the experimental procedure and would return to the floor of the cage and lever press obtaining a reinforcer. On occasions Joey would return to the nesting box but more often was observed on the floor. Consequently, as a result of infrequent views and being outside the scope of the study a topography of behaviour could not be examined in any detail.

In Experiment 2, a second response lever was provided as an attempt to offer an explicit opportunity for another behaviour that could be monitored. The lever was on the right hand side in close proximity to the DRL response lever. It was available to respond on but did not provide access to reinforcement. Overall responding on this lever was minimal (refer *Figure 7*) with initial impressions revealing that animals responded poorly. The data showed flat-lined at zero-s and just above. This suggests that providing an explicit alternative option for behaviour in this procedure was irrelevant because it was generally unused. This finding was also somewhat unexpected. As pointed out earlier it has been argued (Laties, et al., 1965; Laties, et al., 1969) that animals will use an explicit alternative response during the delays if one is made available. Thus given the animals familiarity with levers it was expected that the possums would easily utilise the alternative lever during the time delays. Some explanations for these findings are explored below.

Firstly it might be that the possums may not have required access to an explicit alternative response lever during the delays because the possums had acquired alternative behaviour of their own; either gained naturally or as a result of being involved in Experiment 1 prior to this one. Secondly, it was surmised that collateral behaviours might have come about as a direct result of being exposed to extensive opportunities during Experiment 1 where, because the possums were exposed to many opportunities to adjust to the DRL contingency at each DRL value, they accordingly developed their own alternative behaviour. Perhaps, if Experiment 2 was run first we may have seen different results.

Nevertheless, although the lever could function as an alternative substitute to a behaviour it was not utilised in the manner suggested in the original hypothesis. After completing a full experiment of responding to low IRT, which incremented slowly over a large number of trials, it is proposed that the animals developed their own alternative or collateral behaviour. The collateral behaviours may have successfully aided the possums to mediate the IRT and gain access to reinforcement and as a consequence the second lever in Experiment 2 became irrelevant.

In Experiment 1, the possums gave the impression of functioning on the DRL schedule of behaviour especially at the beginning of the experiment on the very short durations from 0.2-s to 15-20-s. When reviewing the data in *Figure 5*, the average successful IRT with increasing DRL, gave the impression of successfully meeting the DRL contingencies where the data showed responding just above the curve of the DRL value. However, this impression may be false.

Upon closer inspection, the data in *Figure 4,* logged average DRL, in fact shows unsuccessful responding under the DRL curve, especially from around 15-s onward.

If we examine responding in two parts, low DRL values and high DRL values, both patterns of responding can potentially be explained by something other than successfully responding to the DRL contingencies. The delays in the early low DRLs were very short (beginning at 0.20-s) and the animal's free rate of responding was slower than the programme DRL leading to the animals always being successful on the DRL. This may not have been because the possums were sensitive to the reinforcers and punishers but because the rate of responding by possums was generally slower than the DRL requirement and so it inevitably fulfilled the requirement. If this were true, then we would expect to see that the average IRT through all of the shorter DRL would be the same. Thus when inspecting *Figure 3* and *Figure 4,* this is the case. All early IRT rates are similar irrespective of the incrementing DRL value at around 5-s to 10-s or higher. This suggests that IRT responding for shorter DRL was not sensitive to the DRL contingency and that in fact, what is being shown is the actual time it took for the possum to respond that produced the apparent success because possums are naturally slow animals. Therefore, whilst it appeared that the DRL contingencies were being met, it is argued here that it is likely that the DRL contingencies were not being met at all.

When the higher DRL values are investigated, performance appears to be meeting the DRL requirement consistently at the DRL value and not above the DRL value. Upon reconsideration of the experimental procedure, it is noted that after 300 successful trials the DRL is increased and that this will occur irrespective of the number of sessions or trials required to achieve the 300 reinforcers. In short, the procedure is one in which the possum cannot fail at any particular DRL as long as they are given enough time to finally achieve all 300 reinforcers. Thus it appears that the apparent responding to the DRL occurred not as a result of the DRL consequence but that when allowed a large enough number of trials, the animal's accidentally achieved the 300 required successful responses before moving on to the next DRL condition. So again, whilst it appears that the DRL contingencies were being met, it is argued here that this may not be the case at all (see *Figure 3)*.

Thus, overall the animals appear to be successful at higher DRL's but only because of the high number of opportunities given to attempt to be right. Generally, under normal conditions very high rates of failure would not typically be interpreted as being effective or successful. *Figure 9* shows clearly that it took multiple days for the possums to complete DRL at higher values thus suggesting that performance was simply an accidental by-product of the procedural arrangement. That being so, it is proposed, that the 'apparent' effective DRL contingency was not responsible for DRL responding at high DRL. Upon reflection a more honest criterion could have been arranged implementing a limited hold to curb excessive responding, whereby the animal would have no more than *'n'* days or *'n'* trials to obtain 300 reinforcers. This would likely have better reflected the falling off or the inability of the animals to complete the data, which would have been more consistent with previous research.

When considering the alternative explanation for the apparent effectiveness of low DRL and high DRL, it appeared that overall the animals were not able to respond efficiently to the DRL contingencies in this procedure.

Therefore, whilst it appeared that the possums were successfully following the DRL contingencies, upon closer inspection, it showed that they were not. *Figure3* shows large clusters under the DRL criterions. Consequently, if this finding is more generally true then there may be implications for applied procedures that wish to use pure DRL schedules of behaviour in the future.

It is a popular idea in applied behaviour analysis that DRL can efficiently reduce undesirable behaviour because it lowers the rate of the behaviour that you do not want. However, a downside with DRL schedules is that in order for an organism to inhibit one behaviour they may inadvertently start engaging in another behaviour. Experimental studies such as Laties et al. (1965) and Laties et al. (1969) have studied the role of collateral (or alternative) mediating behaviour with relative success noting that the behaviour had a "mediating function" (Laties et al., 1969, p. 53). However, although the studies have been demonstrated as effective, most experimental studies only use two parameters or two different levels of DRL requirement. For example, Laties et al. (1969) used two values, DRL 36 and DRL 48 to assess DRL performance. Furthermore, there is very little evidence in the applied literature to support experimental laboratory DRL having any notable advantage in applied procedures (for instance, Laties et al., 1965; Laties et al., 1969; Dietz & Repp, 1973; Deitz et al., 1978). Upon closer inspection of the applied literature, it is noted that the procedures were not pure DRL schedules because competing parameters were included in the schedules. For instance, in Dietz & Repp, (1973) and Deitz et al. (1978) verbal reinforcement and physical cues were given by the experimenters, consequently teaching the participants, along the way, how to engage in alternative responses during the IRT that would result in meeting the DRL requirement. As a result, it is difficult to draw any conclusions about whether DRL do or do not work in the applied setting. Furthermore it throws doubt on whether the procedures are in fact DRL schedules or if they are instead another schedule of behaviour such as, DRO (Differential Reinforcement of Other Behaviour), as in, Lindberg, Iwata, Kahng, & DeLeon, 1999; or DRA (Differential Reinforcement of Alternative Behaviour), as in, Deitz & Repp, 1973.

In view of the concerns regarding applied DRL procedures and the limitations in experimental research, the study presented here sought to explore further experimental and applied research. This study parametrically examined DRL with possums in a thorough, detailed and systematic analysis across a large number of values and across a large number of days. This may be the first time that a study has parametrically investigated DRL. The DRL study showed poor levels of efficiency and that possum's behaviour was not brought under operant control. Overall, the study revealed the possums failed to perform on DRL in both experiments.

The second response lever did not function as a discriminate stimulus and thus DRL performance was not improved by its presence and showed to be ineffective. In consideration of these findings, doubts could be raised about the robustness of DRL procedures in animal research. This being the case we are left to conclude that the idea of DRL as a useful technique in applied behaviour analysis should be taken up with some caution.

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