An Investigation of Suboptimal Choice By Possums

A thesis

submitted in partial fulfilment

of the requirements for the degree

of

Master of Applied Psychology (Behaviour Analysis)

at

The University of Waikato

by

Stephanie Anne Hill

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

2016

Abstract

This study addressed the question of whether an overall preference for a suboptimal choice, previously found in pigeons (Stagner and Zentall, 2010), would be replicated with five brushtail possums. In Part One of this experiment possums responded on a concurrent-chain procedure where both alternatives had fixed-ratio 1 schedules in the initial link and a fixed-interval 10s in the terminal link. Two stimuli outcomes (four line orientations) are presented on the alternatives based on a probability of 0.20 or 0. 80. The left produced a discriminative stimulus with the right reinforcing on half of trials (20:50). Three of the five possums showed a consistent preference for the optimal alternative (50%), while the others showed a preference for the suboptimal (20%). When data was averaged possums showed a preference for the optimal alternative, which was not consistent with Stagner and Zentall's (2010) earlier findings. Part Two of this investigation replicated Gipson, Alessandri, Miller and Zentall (2009), probabilities of stimuli appearing were changed to 50/50, with a discriminative stimulus on the left alternative and the probability of reinforcement on the optimal alternative increased to 75% (50:75). The discriminative stimuli were now more predictable than previously, when this was not present all possums showed a preference for the suboptimal alternative. When discriminative stimuli were associated with both alternatives (20:50), replicating Stagner, Laude and Zentall (2012), all possums showed all possums optimal preferences. An overall preference for the optimal alternative, seen during this study, is consistent with the findings reported in a more recent study by Trujano and Orduña's (2015) with rats. This overall optimal preference is somewhat consistent with optimal foraging theory, however, this does not account for the suboptimal choices made by some possums. The suboptimal preferences seen by two possums in Part One and all in Part Two also loosely support previous findings that pigeons are under the control of discriminative stimuli.

Acknowledgements

Firstly I would like to thank my supervisors Professor Mary Foster and Dr. Lewis Bizo for your amazing knowledge, your encouragement and support. I would especially like to thank Mary for her patience over the past two and a bit years, and Lewis for continuing to contribute to this thesis even after he left the university. Both of your input has been greatly appreciated, and I wouldn't have got to this point without it. I would also like to acknowledge Jenny Chandler, without you I would not have had an experiment. You have helped me in so many ways over the last few years. Thank you for your wise words, the laughs, and for looking after the possums.

The 'Possum girls' Katrina, Steph and Vicki, thank you ladies for listening to me complain, providing me with time away but also for helping me to run my experiment as I wouldn't be at this point if you hadn't. I also want to thank Kim, Sinead, Tegan, Surrey, Karen and the behaviour lab students, and all my other friends, for being there to help, but for reading my work, and making sure I got some 'sane time', without you I would have not been able to get through this feat.

To all my workmates I have had over this journey; you have all supported me in so many ways, listened to my rants about my experiment when it was going well or not and just been there to provide some laughs when things were stressful, Thank you.

My parents, Tony and Angela, and sister, Brooke, thank you the most, not only have you all supported me along this incredibly long journey; you continue to support me no matter what. Without your support I wouldn't have even made this step in the first place. You guys are my rock and I love you to the moon and back.

Finally I want to thank my amazing partner, Ashton, you came along half way through this journey and have supported me regardless, and you continue to support my dreams. You have put up with all of my stress, my rants, and my tears and have loved me despite this. You have been a rock, my number 1 supporter and without you I wouldn’t be here, so thank you from the bottom of my heart. I love you, infinity.

Table of Contents

List of Tables

List of Figures

List of Appendices (on CD)

Appendix A: Ethics approval form- Protocol 916.

Appendix B: Possum weights.

Appendix C: Spread sheets of raw data.

Introduction

Gambling is a problem in New Zealand. It was recently found in a study that eighty per cent of participants surveyed took part in some form of gambling, with 1 in 5 who did so either weekly or more frequently (Abbott, Bellringer, Garrett & Mundy-McPherson, 2014). Because of the addictive nature of gambling, there are ethical and practical considerations that make it difficult to directly study gambling with humans using experimental techniques that modify the frequency of payoffs and their associated cues. However, there have been a number of animal studies that have used experimental techniques to study the phenomena of gambling (for example: Madden, Ewan & Lagorio, 2006; Peters, Hunt & Harper, 2010; and Weatherly & Derenne, 2007).

Concurrent-chain procedures have been one method used to investigate the phenomena of gambling with animals. With concurrent-chain procedures, two alternative choices are presented to pigeons; one with an intermittent reinforcement which is considered the gambling-like choice. Where the ways in which the outcomes are arranged and delivered are said to be similar to slot machines and lotteries (Pattison, Laude & Zentall, 2013; Zentall, 2014). On the gambling like alternative, two stimuli outcomes are available, associated with the first stimulus is a win, this outcome has a low probability of reinforcement that is paired with a discriminative stimulus. The second outcome represents a loss or the losing outcome; this has a higher probability of non-reinforcement with a stimulus that confirms non-reinforcement. Choice for this alternative is said to represent the same choices humans make when choosing to gamble (such as participating in lotteries or playing slot machines; Laude, Beckman, Daniels, & Zentall, 2014; Pattison, Laude & Zentall, 2013; and Zentall, 2014). The other alternative, or the non-gambling option, provides a higher overall reinforcement but has no programmed discriminative stimuli. Pigeons have shown to consistently make a choice and show a preference for the gambling-like alternative and thus are provided with less overall reinforcement. Zentall terms this type of choosing a “suboptimal choice”.

Suboptimal choice has been described as being maladaptive (Zentall, 2011), where humans and animals make a choice or show a preference for an option that provides less overall food than the other, when it is paired with discriminative stimuli, this has also been termed a low probability alternative. Pigeons will show a preference for the former over an alternative that provides a higher overall food outcome that has no associated stimuli, this alternative is often termed the high probability alternative. A suboptimal choice is said to be maladaptive in that it goes against the basic animal instinct of maximising gains or food intake in order to survive (Zentall, 2011).

A study investigating the suboptimal choice procedure with humans indicated that the pigeon suboptimal choice model is analogous to a human gambling task and thus can be said to represent human gambling. The procedure was a computer based task that provided reinforcement at the same rate as the previous pigeon studies using a similar concurrent-chain procedure (Molet et al., 2012). They found that individuals who self-reported as being gamblers were more likely to choose the suboptimal choices, which was similar to the results with pigeons and showed that, like pigeons, humans make similar suboptimal choices.

Concurrent-chain Procedures

Concurrent-chain procedures have been used in a number of studies to examine choices made by different animals (Fantino, 1969), as well as to investigate suboptimal choice. Concurrent-chain procedures are characterised by alternate response keys and multiple schedules, which are available at the same time. These are followed with a chain of responses which leads to reinforcement with food (Ferster & Skinner, 1957).

The initial link of the chain is where the choice is determined by conditioned reinforcement (Dunn & Spetch, 1990). Once this initial link is chosen the other choice becomes inoperative, that is, when a choice of one alternative is made on the initial link the other is not available until the completion of that selected chain (Dunn & Spetch, 1990). A second stimulus (or more, based on the number of links in the chain) then appears- known as the terminal link- and then based on a schedule of reinforcement, a reinforcer is delivered (Moore & Friedlen, 2007).

Links can be added to the chain requiring more responding until the terminal link is reached for reinforcement. When an animal responds on the initial link and is then presented with the terminal link the behavioural choosing is reinforced with the presentation of the terminal link stimuli. A response on the second stimulus, or in the terminal link, is then consequently reinforced with a primary reinforcer (typically food; Autor, 1969).

Early Concurrent-chain Procedures Investigating Intermittent Reinforcement

Early concurrent-chain procedures investigated intermittent reinforcement using two key alternatives. One of these alternatives leads to reinforcement on every trial (100%) and the other leads to reinforcement on 50% of the trials. Early findings were that pigeons would often choose the alternative that provided the intermittent reinforcement over the one that provided the high rate (Kendall, 1974). It was here where it was initially suggested that the information provided in the discriminative stimulus was the reason for the preference for this alternative (Kendall, 1974).

This study was replicated with an altered procedure, so that both the initial link keys were lit and when the pigeons made a choice the key that was not chosen went dark (Fantino, Dunn & Meck, 1979). In the earlier studies there was no initial stimuli, both keys were dark until one was chosen (Kendall, 1974). It was argued that this was not a conventional concurrent-chain procedure (Fantino et al., 1979), thus the same parameters were investigated using a conventional concurrent-chain procedure. Under these conditions it was found that pigeons had a preference for the high probability alternative not the intermittent alterative, and thus they had a preference for the option providing more reinforcement. In response to this, Kendall (1985) replicated the conventional concurrent-chain procedure and found, as did Fantino et al., (1979), that the pigeons had a preference for the 100% alternative.

Earlier studies using concurrent-chain procedures with two alternative choices to investigate intermittent reinforcement have shown that pigeons will have a preference for a suboptimal alternative (Fantino et al., 1979). When this procedure was modified a preference for the alternative that provided a consistent reinforcement was found (optimal alternative; Kendall, 1974)).

Suboptimal Choice Studies

Zentall and his colleagues furthered these earlier experiments, concerning intermittent reinforcement, to investigate what were the possible mechanisms for these suboptimal choices that pigeons make. Roper and Zentall (1999) used a concurrent-chain procedure with different coloured stimuli to investigate pigeon's choice when the probability of discriminative stimulus associated with reinforcement appearing in the terminal link, vas varied between 12.5%, 50% and 87.5%. This was to identify if pigeons had a preference for an alternative which included a discriminative stimulus. It was found that there was a strong preference for this alternative. Investigation then turned to the strength of the preference for the discriminative stimulus. This was done by increasing the peck requirement on the link that lead to the suboptimal choice, to see the effort the pigeons would make in the presence of a discriminative stimulus (Roper & Zentall, 1999). When the probability of reinforcement was higher on the alternative that provided the discriminative stimulus and the peck requirement increased pigeons switched to the alternative that provided 50% reinforcement. This study showed again, that when there was a discriminative stimulus, pigeons will have a preference for that alternative. When the peck requirement increases, their preference switches to the non-discriminative stimulus alternative.

In order to investigate if there was a condition where the low rate reinforcement alternative would be preferred over a high rate alternative; Gipson, Alessandri, Miller and Zentall (2009) replicated earlier research with concurrent-chain procedures. Pigeons were split into two groups; these were termed the ambiguous and unambiguous group. In the ambiguous groups, the stimulus associated with the unchosen alternative in the initial link stayed lit, and in the unambiguous groups the stimulus associated with the unchosen alternative in the initial link was turned off. On the left alternative both the red and green stimuli appeared 50% of the time with red providing reinforcers on every occasion it was presented and green stimulus resulting in no reinforcement when presented. On the right alternative, the blue stimulus led to reinforcement half of the time it was presented.

Gipson et al. (2009) found that most of the pigeons in the unambiguous group, where the unchosen stimulus was turned off, showed a preference for the alternative that lead to 100% reinforcement (the suboptimal choice). In the ambiguous group, where the unchosen alternative stayed lit, there was variation within pigeons; 3 had a moderate preference for the 100% alternative (suboptimal choice), 3 had a preference for the 50% alternative (optimal choice) and the other 2 showed indifference.

It was speculated that the preference for the 100% alternative over the 50% alternative was due to a single stimulus leading to 100% reinforcement (Gipson et al., 2009). Previous research (Mazur, 1996) showed that when there was a random presentation of two stimuli, it decreased the preference for the low probability alternative. Therefore, Gipson et al. (2009) added a second alternative to the right key where both stimuli appeared 50% of the time with a probability of reinforcement of 75%. Results showed that the majority of the pigeons had a reliable preference for the 50% (suboptimal) alternative, with only three that had a preference for the optimal alternative (75%). This study showed that even by adding a second stimulus to the high probability alternative, pigeons continue to have a preference for the low probability alternative. Additionally, it shows variation between subjects responding.

Because of the earlier findings (Roper and Zentall, 1999; Gipson et al., 2009) Stagner and Zentall (2010) investigated if pigeons would make the same choices when the probability of reinforcement was less. The general procedure of this study was the same as Gipson et al.'s (2009) concurrent-chain procedure, using the same colour stimuli; however the probabilities of reinforcement and probability of the stimuli appearing was changed. On the left key the red stimulus signalled reinforcement 100% of the time and appeared on 20% of the trials. While the green stimulus appeared on the remaining 80%, and did not produce reinforcement (termed the suboptimal alternative; 100/0). On the right key both the yellow and blue stimuli signalled reinforcement on 50% of the trials, with the blue appearing 20% of the time and the yellow on the remaining 80% (termed the optimal alternative; 50/50).

Pigeons quickly developed a preference for the low probability alternative with a discriminative stimulus by the 12th session, and when the probabilities were reversed the pigeon's choice shifted to maintain this preference. When Stanger and Zentall (2010) removed the discriminative stimuli (changing the probability of reinforcement on both stimuli to 20%) the pigeons shifted their preference to the high probability alternative (optimal choice). This furthers previous studies that show pigeons have a preference for the suboptimal alternative or the alternative that produces less reinforcement. This also shows that when discriminative stimuli are removed then the optimal alternative is preferred. Again this suggests that the presence of a discriminative stimulus encourages a preference for a low probability alternative.

The Change of Variables and its Effect on Suboptimal Choice

Zentall and his colleagues have conducted a number of studies where different variables were changed to identify the strength in pigeon's preference for the discriminative stimuli and to identify if there are other mechanisms to account for the suboptimal choices the pigeons made. A number of studies have altered the stimuli to investigate the effects it has on choice. The purpose of these studies was to see how stimuli affected choice and if changing the discriminative stimuli also changed preference. These studies used the same concurrent-chain procedure as Zentall’s earlier studies, with the same or similar stimuli and probabilities.

A study was conducted, that removed the discriminative stimuli aspect of the low probability alternative, so that there was nothing that signalled reinforcement (Zentall & Stagner, 2011a). This was to determine if the preference for the discriminative stimulus alternative was due to the pigeons avoiding the uncertainty of the non-reinforcement, or the presence of a stimulus that predicted reinforcement. When the discriminative aspect of the low probability alternative was removed, it was found that pigeons would prefer the optimal alternative. Providing more evidence for the theory that discriminative stimuli are responsible for the preference for the low probability alternative.

In Stagner, Laude and Zentall (2011), their pigeons were randomly assigned to group where the house light was a discriminative stimulus for reinforcement or no reinforcement. This was to investigate whether or not the preference for a discriminative stimulus, was due to a reduction in conditioned inhibition for the stimuli that signalled the absence of reinforcement. To overcome this, the houselights were included as stimuli for the non-reinforcement, so that the pigeons were not able to turn away from the stimuli. It was found that pigeons preferred the low probability alternative as in other studies. Therefore, it was concluded that it was not the avoidance of the conditioned inhibitor, or the non-reinforcement stimulus that was the mechanism for the preference for the discriminative stimuli alternative (Stagner, et al., 2011).

It was suggested that pigeons ignore the stimuli that signals an absence of reinforcement, but choose the low probability alternative because of the value of the discriminative stimuli (Stagner, Laude & Zentall, 2012). So to investigate this discriminative stimulus were added on both alternatives to further explore the mechanisms of suboptimal choices. Alternatives were changed so that both had discriminative stimuli, with the left alternative producing reinforcement on 20% of trials and 50% on the right alternative. Stagner et al. (2012) found that pigeons were indifferent in their choice when discriminative stimuli were on both alternatives. However when only one alternative had a discriminative stimulus pigeons showed a preference for that alternative. This again shows that when there is a discriminative stimulus present, pigeons will choose that alternative and when both alternatives have discriminative stimuli then pigeons are indifferent.

Zentall, Laude, Stagner and Smith (2015) investigated whether or not it was the effect of a conditioned reinforcer that determined choice, or the frequency of reinforcement. There were two groups of pigeons with two probabilities of reinforcement, 50/70 and 25/75. It was found that both sets of pigeons started the training sessions with indifference and then increased their preference for the suboptimal choice at the same rate. This study shows that regardless of the probabilities, pigeons will consistently choose the alternative that provides a discriminative stimulus.

The above studies (Stagner et al., 2011: and Zentall & Stagner, 2011a) illustrate that when the discriminative stimuli is removed, pigeons will show a preference for the high probability alternative, and when both alternatives have a discriminative stimuli pigeon’s show indifference. Thus the discriminative stimuli are a strong mechanism for the pigeon's preference regardless of the type of stimuli or the differences in probabilities of reinforcement.

Zentall and his colleagues have also investigated the effect of reinforcer size on preference for the suboptimal choice; it has shown in these studies that reinforcer size affects suboptimal choice. Zentall and Stagner (2011a) furthered their study by investigating the effect of reinforcer size on choice. When the suboptimal choice resulted in more food (10 pellets less often) than the optimal choice (3 pellets more often), pigeons showed a strong preference for the suboptimal alternative with more pellets (Zentall & Stagner, 2011a).

To determine the strength of the preference for the discriminative stimuli, a number of studies using the concurrent-chain method have adjusted the terminal link times to observe the effects on suboptimal choices. This has been done by decreasing the time that the stimuli were presented before reinforcement or black out (Zentall & Stagner, 2011b). The terminal link duration was decreased from 10-s to 0-s, for the non-discriminative stimuli side, to assess the strength of the preference. They found that when the duration of the terminal link was reduced, pigeons switched their preference from the low probability alternative to the high probability (Zentall & Stagner, 2011b). Thus when the terminal link time on the discriminative stimuli was longer than the non-discriminative stimuli alternative, then the pigeons choose the alternative that had no discriminative stimuli or the optimal choice.

It has been speculated that there is a relation between impulsivity and suboptimal choosing (Laude et al., 2014). In a study by Laude at al. (2014), pigeons were exposed initially to a delay discounting procedure first, to determine their impulsivity before moving on to the suboptimal choice procedure. They found that when pigeons were more impulsive in the delay discounting procedure, they were more likely to choose the suboptimal alternative over those who had low impulsivity in the delay discounting procedure. Laude et al. (2014) speculated that the mechanisms behind the choices may be similar; however, it is unclear what drives these choices. This indicates that impulsivity may be a driver for the suboptimal choices, similar to human gambling (Laude et al., 2014).

Food restriction has also been investigated to see if this effects optimal choosing using the same concurrent-chain procedure. Pigeons' food was restricted to maintain them at 75% and 90% of their free feed body weight. The high-restriction group showed preference for the lower probability alterative, while the low-restriction group showed preference for the higher food probability alterative (Laude, Pattison & Zentall, 2012). This study suggest that not only does magnitude of reinforcement affect choice, but when their diet is restricted pigeons will increase their likelihood of choosing optimally.

Environmental enrichment has also been investigated to see if that affects suboptimal choosing (Pattison et al., 2013). When pigeons were allocated to an enriched environment or a non-enriched environment (control), it was found that the pigeons allocated to the non-enriched environment quickly established a preference for the suboptimal alternative. In comparison, the pigeons allocated to the enriched group showed a preference for the optimal choice. This experiment indicates that having the ability to be in an environment that provides access to other pigeons in a flight cage or other more stimulating environment, has an effect on choice. It is suggested that being deprived of stimulation (by being in isolation), could mean that the pigeons are more sensitive to the conditioned reinforcers (discriminative stimulus) and thus be more likely to choose the suboptimal choice than pigeons that have access to an enriched environment (Pattison et al., 2013). It has also been found in other studies that pigeons that were allocated to a socially enriched group initially choose the optimal alternative. As the condition progressed, the pigeons made a switch the suboptimal alternative, though this was a lot slower compared to pigeons that were isolated (Laude et al., 2014).

Overview

In a quantity of studies investigating intermittent reinforcement using concurrent-chain procedures shows that under a number of contingencies, pigeons are more likely to show a preference for the suboptimal choice. This preference for the suboptimal alternative is seen when there is the presence of a discriminate stimulus, there is more food associated with the suboptimal alternative, when pigeons have higher food restrictions, are not in enriched environments, when terminal link times are equal and when pigeons are considered to be impulsive. On the other hand, pigeons have a preference for the optimal alternative when there is no discriminative stimuli present, they have less food restrictions, are socially enriched, and when the cost for the suboptimal choice is higher.

What Could Account for Suboptimal Choosing?

In light of the above findings, there have been a number of theories that could account for these choices. These are:

Optimal foraging theory: Optimal foraging theory states that animals will forage to maximise their food amount while using the least amount of energy (Stephens and Krebs, 1986). Therefore it is an innate mechanism that drives animals to optimise their food intake, so animals will be more likely to choose an alternative that provides them with more food and increase their chances of survival. This would be making an optimal choice, however as seen from the literature, pigeons do not make these choices. Stagner and Zentall (2010) reported optimal foraging theory and questioned why pigeons chose the low probability alterative (i.e. not optimising food amount), which again goes against basic instinct of maximising their gains.

The Law of Effect: The ‘Law of Effect’ would support the optimisation of food. This states that animals are likely to make a choice that will eventually lead to the most reinforcement (Pierce & Cheney, 2008). That is, animals have a tendency to choose an alternative which is associated with the higher probability of reinforcement (Stagner & Zentall, 2010). Studies that have found that pigeons show a preference for the high probability alternative when there are no discriminative stimuli (see: Dunn & Spetch, 1990; Spetch, Belke, Barnet, Dunn & Pierce, 1990) and thus increasing their optimisation of food. This also shows support for conditioning (as discussed later), as when there are no discriminative stimuli pigeons make a preference for the optimal choice.

The Law of Least Effort: The law of least effort states that a choice that requires less effort is going to be more preferred (Stagner & Zentall, 2010). Roper and Zentall (1999) found that when the cost or the peck requirement was high then their preference switched. Suggesting that as effort required to gain reinforcement is increased preference will change to match the alternative that requires the least amount of effort (i.e. less peck responses)

Conditioned Reinforcement and Discriminative Stimuli: Conditioned reinforcement has been most commonly recognised as one of the mechanisms for suboptimal choices. Conditioned reinforcement theory asserts that a preference will be based on a series of rules or what has been reinforced in the past. If a stimulus has been reinforced in the past through conditioning (i.e. pecking a key for reinforcement), then the stimuli that is signalling reinforcement, is what makes a discriminative stimuli more preferable (Dinsmoor, 1983).

Therefore, because of conditioning where a stimulus produces reinforcement, animals are likely to choose options that provide information of reinforcement. Suboptimal choice procedures have shown this preference, they have shown that regardless of the amount of reinforcers, animals will choose an alternative that provides a signal to reinforcement (discriminative stimuli).

Information Theory: Information theory assumes that all information that you are exposed to determines your choice and thus reduces uncertainty (Stagner & Zentall, 2010). Therefore, whenever there is a discriminative stimulus, the information received from this stimulus will determine choice. This is because the outcome of the choice becomes more certain (Dinsmoor, 1983). Consequently, the animal will be less likely to choose an alternative that is ambiguous, and thus avoid this option.

Stimulus Control: Research with schedules of reinforcement have also shown the strength a stimulus has on an organism's behaviour, thus suggesting that an organism will be under the control of a stimulus (Ray & Sidman, 1970). This means that a stimulus can control behaviour; thus, when a discriminative stimulus is available it is likely that this will affect behaviour. When the stimulus is changed (or removed) then the behaviour will also change. When a discriminative stimulus is available the outcome becomes more certain. Uncertainty of reinforcement affects behaviour and whether or not a choice is perceived as optimal and self-control is shown (Logue, 1998). This supports information theory in that when reinforcement is uncertain at such a rate that it is not likely, then self-control is not seen to be apparent and animals will make a choice for an alternative that they expect to be the most certain.

Suboptimal Choice Experiments with Other Animals

Suboptimal choices have been largely investigated in pigeons. Further research with other species of birds (hens and roosters) and with rats have investigated suboptimal choice using concurrent-chain procedures.

Ngatai (2013) investigated suboptimal choices with hens using Stagner and Zentall's (2010) procedure to determine if hens would choose the suboptimal choices as the pigeons. During the replication, Ngatai's (2013) hens consistently showed a preference for the suboptimal alternative, even when reversed. When Ngatai (2013) provided an alternative where the pigeons had equal reinforcement rates on either side (i.e., 50% reinforcement rate on both left and right alternatives) then the hens showed variation in their choice with either larger increases and decreases or a slight preference. When the probabilities were changed on the suboptimal alternative choices (90/10, 80/20, 60/40) it was found that half of the pigeons continued to choose the suboptimal choice, and the other half had more variation in their choosing, with one having an optimal preference across these conditions. There were some individual differences across the hens, however overall they showed very similar response types. Ngatai (2013) provided individual hen data and graphs, while most studies reported here have shown averaged data (i.e., Stagner and Zentall, 2010)

Yang (2015) investigated suboptimal choice in roosters. She did this by gradually increasing and decreasing the probability of reinforcement for the left alternative. Reinforcement associated with the red stimulus was increased from 50% to 100%, and decreasing the probability of reinforcement associated with the green stimuli from 12.5% to 0%. It was found that most of the roosters switched their choice from the optimal choice to the suboptimal choice as the probability of reinforcement changed. Similar to Ngatai (2013), Yang (2015) reported individual data. Two of the roosters had more of an optimal preference throughout the five conditions. The other rooster showed a preference that moved from optimal to the suboptimal alternative as the conditions progressed, however in the replication the rooster had a strong preference for the optimal alternative across all conditions.

Rats have been found to not make suboptimal choices like pigeons (Trujano & Orduña, 2015). Trujano and Orduña (2015) adapted Zentall's suboptimal choice procedure for use with rats and investigated suboptimal choices (coined non-optimal choices in this study) so that they could be integrated with neurobiological studies completed with rats around impulsivity. It was found that in the suboptimal choice condition and the reversal, the rats consistently showed a preference for the optimal choice. When the terminal link time was increased to FT 30s, they still found that the rats showed a preference for the optimal alternative. Trujano and Orduña (2015) also exposed the rats to a condition where there were equal probabilities on each of the alternatives (50:50). In this condition, they found the rats showed a preference that was indifferent.

Capabilities of Brushtail Possums

Suboptimal choice procedures have not been studied with possums. In the present experiment possums will serve as subjects. Possums are considered a pest in New Zealand and were initially brought to New Zealand for their fur (Pracy, 1962). There have been a number of laboratory studies in the University of Waikato's Animal Behaviour and Welfare Research Unit studying possum behaviour. However there have not been a large number of studies investigating intermittent reinforcement using concurrent-chain procedures. Possum studies have typically centred on pest control. This includes food preference (Cameron, Bizo & Starkey, 2013, Jenkins, 2014; Cronin, 2012), visual discrimination (Signal, Temple & Foster, 2001), performance on fixed ratios (Hudson, Foster & Temple, 1999) and auditory abilities (Signal, Foster & temple, 2001; Osugi, Foster, Temple & Poling, 2011).

There have been studies that have investigated possums' visual abilities, Vanstone (2006) found that possums had a lower accuracy discriminating the red stimulus from others, it was concluded that this may be due to possums not being able to detect that wavelength colour. Thomas and Maddigan (2004) suggest that possums, like other animals may have only dichromatic vision, meaning that it is more difficult for animals, to discriminate between medium and long wavelengths (green, yellow, brown, orange and red). However, Vanstone's (2006) finding could be due to the red lights in the experimental rooms. Based on this it would not be appropriate to investigate possums' choice using Stagner and Zentall's (2010) original Red/Green and Blue/Yellow stimuli colours, thus a change in stimuli was supported.

Hardaker (2006) investigated possums' ability to match to sample using different stimuli. It was found that possums were better at discriminating when they were presented with horizontal or vertical lines over flashing or still lines. Therefore, coloured stimuli would not be appropriate for this study and that possums were better able to distinguish between horizontal and vertical stimuli which encouraged the use of these stimuli in the current procedure.

The Present Experiment

Stagner and Zentall's (2010) experiment, as discussed earlier, looked into suboptimal choices in pigeons using a concurrent-chain procedure. They looked into whether pigeons would choose the low probability alternative if it signalled reinforcement (Stagner & Zentall, 2010), and found that pigeons showed a preference for the suboptimal alternative that signalled reinforcement. Ngatai (2014) and Yang (2015) replicated these experiments with hens and had similar findings to Stagner and Zentall (2010).

It was initially hypothesised that overall, possums would show a preference for the suboptimal alternative and as the probabilities were altered, possums would shift their preference to the alternative where there was a discriminative stimulus. It was also expected when the contingencies were reversed then the possum's choices would also reverse.

The purpose of Part One of this experiment was to replicate the suboptimal choice experiment with possums to determine if the results of previous studies will be found in marsupials using different stimuli and how they would respond when both alternatives had the same reinforcement ratios. It was hypothesised that when the low probability alternative was predictable, the possums should shift their choices to this alternative and chose suboptimally, as reflected in earlier studies. It was predicted that possums would show a preference for the discriminative stimuli when it was available and when reversed, possums will follow the suboptimal choice

When the probability ratios were such that there was no difference on reinforcement (e.g. 50% reinforcement on both alternatives) it was expected that the possums would show indifference as the rate of reinforcement would be the same on both the left and right, as shown in Ngatai’s (2013) hens.

The second part of this experiment investigated the strength of the possums’ choices in Part One. Part Two replicated Gipson et al.’s (2009) experiment two, where pigeons had a preference for the suboptimal option. This was followed by a replication of Stagner, Laude and Zentall’s (2012) study where pigeons were indifferent. Initially it was expected that the possums would, like the pigeons, show a preference for the suboptimal alternative and then show indifference. When these conditions were reversed it was also expected that they would follow this trend in choice. Hence, the current experiment assumes that under the suboptimal choice procedure, possums, like pigeons will make suboptimal choices and follow this preference where discriminative stimuli are available.

Method

Subjects

Six Brushtail possums (*Trichosurus Vulpecula*) were the subjects for this study. Four possums were female: Lottie (aged 1 year), Caper (9 years), Taylor (8 years) and Charlotte (11 years), and two male: Peppi (8 years) and Hasty (approx. 9 years). Lottie was experimentally naïve; the other five had been involved in previous experiments where they were required to push a lever for food reinforcement. The use of possums in this experiment was approved by the University of Waikato Animal Ethics Committee, (AECN: 916, see Appendix A for full ethics application and approval).

Possums were housed individually in wire cages in a room set on a reverse 12 hour day/night cycle (see Figure 1). The possums had constant access to water. Experimental sessions were scheduled 7 days a week and began in the dark phase of the 12 hour cycle. Possums were weighed weekly and their diet supplemented with pellets (manufactured by Dunstan Ltd., Te Rapa), dock leaves (*Rumex obtusifolius,* a common pasture weed in New Zealand) collected in local paddocks, and apple after each experimental session. The amount of supplementary food was adjusted daily to maintain the possums at a stable body weight (see Appendix B).

Apparatus

All experimental sessions occurred in the possums' home chambers, where the response panel positioned at the front of the cage also functioned as the cage door. The cages were 540 mm wide x 850 mm high x 470 mm deep with a wire shelf 250 mm from the top of the cage, and a wooden nest box positioned on top of the cages (see Figure 2). The response panels were situated at the bottom of the

Figure 1: The possums home cage and experimental chambers, which show the nest box attached to the top.

Figure 2: The nest box attached to the top of the cage.

cage and were approximately 550 mm high by 320 mm wide; these were made of plywood with a piece of dark Perspex glued to the cage side of the panel.

A magazine sat at the bottom of the response panel measuring 1300 mm high by 100 mm wide. Possums had access to food reinforcement through a hole 30 mm by 30 mm when the magazine hopper was raised. The reinforcer was a mixture of steam flaked barley and Cocoa Puffs cereal at a ratio of 15:1, which had been found to maintain responding in previous experiments with possums. Caper, Hasty and Charlotte were changed to Extruded Maize (manufactured by Dunstan, Te Rapa) at the beginning of Condition 10, this food choice appeared more preferred for these possums and it was used for the remainder of the experiment.

Above the magazine were three holes though which levers could be placed. The three levers (micro switches) were attached to a bracket which allowed them to be removed when the possums were not in an experimental session. Above the left and right levers were boxes with an array of LED lights which presented the different line orientations during the experiment. The line orientations that these displays produced (using five of the LEDs) were a horizontal, vertical, two diagonal stimuli and a single amber dot (see Figure 5). Above the centre lever was a single amber light.

Experimental events were controlled by a Dell computer with Med-PC® IV software and data was collected using this software as well as being manually written into a data book at the end of each experimental session.

The General Procedure

Possums were able to complete a maximum of 120 trials per sessions. This was broken down into 80 forced choice trials and 40 choice trials that were

Figure 3: Front view of the experimental response panel/ home cage door.

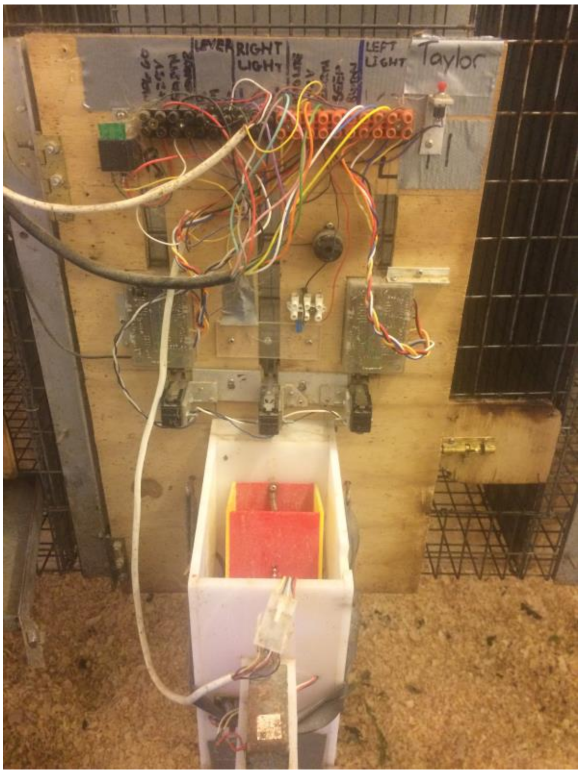

Figure 4: Back view of the experimental response panel/ home cage door.

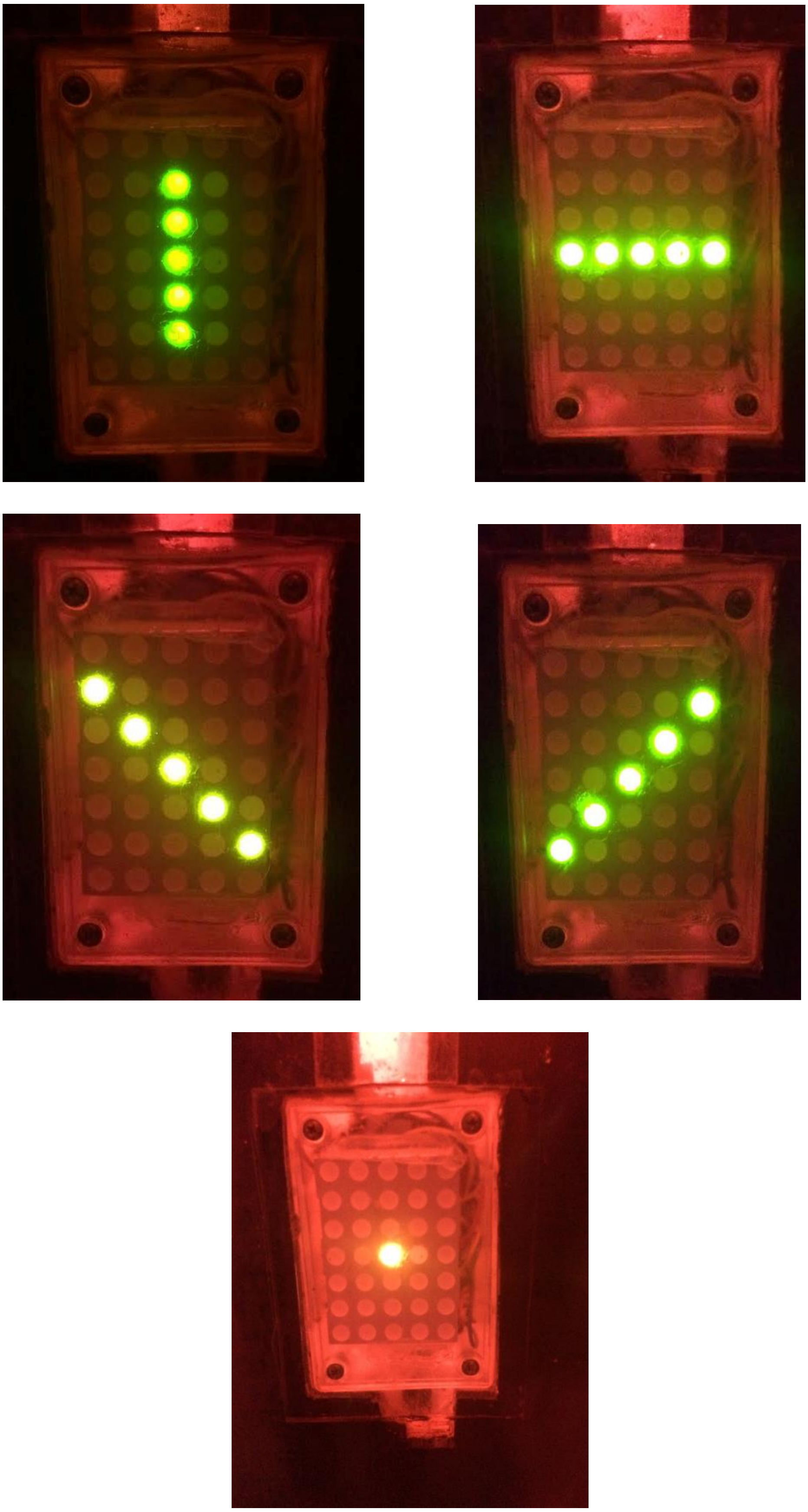

Figure 5: Stimuli presented on the LED screens during the experiment.

randomly presented until all 120 sessions were completed or the 2 hr. (7200 s) time limit was reached.

Possums were exposed to a chained procedure, (shown in Figure 6); the chain began with the centre light illuminated amber. A fixed ratio (FR1) response moved the possum on to the initial link. During a forced choice trial, there was only one of the initial link amber lights illuminated (on the left or the right); this meant that the possum was forced to operate the illuminated lever to continue to the next link. On a choice trial both the left and right initial link amber stimuli were presented and possums had to operate either left or right levers to continue the trial. A response on either lever started the associated terminal link.

During a terminal link, based on the probabilities, a stimuli would presented on the LED screen, these were four line orientations (back slash, forward slash, a horizontal line and a vertical line), shown in Figure F. Stimuli appeared at a rate of 20/80, with forward slash and backslash on the right alternative (20/80). The left alternative had a vertical line orientation l and a horizontal line (20/80). As observed in Figure 5. Once the stimuli in the terminal link were presented a Fixed Time 10 s (FT10) passed before the possums proceeded to the reinforcement. Based on the condition, each of the stimuli was reinforced with a different probability. If the trial was a reinforcement trial, the hopper was lifted for 3s giving the possum access to the reinforcer. If the trial was a non-reinforcement trial then the session would black out and no reinforcer was given. Following this, a 10s inter-trial interval (ITI) passed before the next session began.

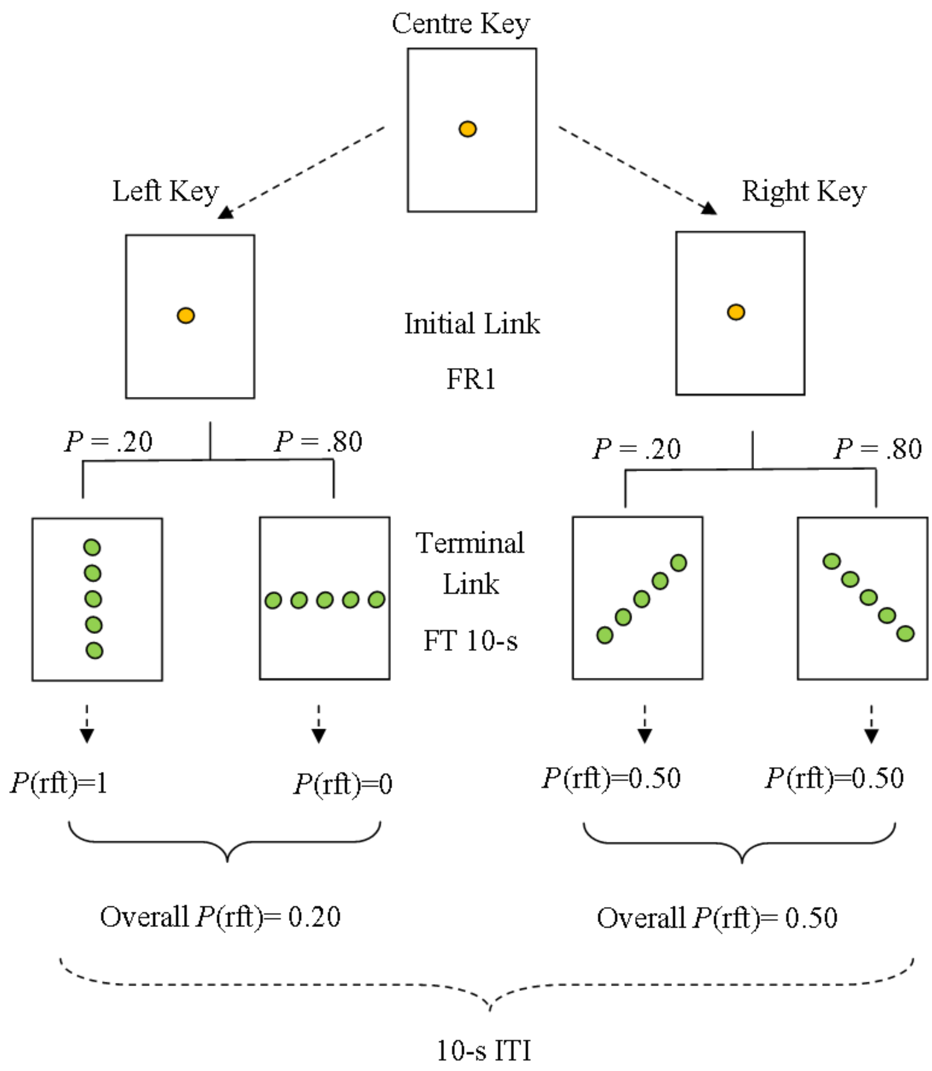

Figure 6: The general procedure of this experiment, this figure illustrates the replication of Stagner and Zentall's (2010) procedure where possums have the choice of two alternatives. The left (suboptimal choice) has two stimuli options, a vertical and a horizontal line (20/80). The vertical line receives 100% reinforcement (discriminative stimulus) while the horizontal line gets no reinforcement. On the right alternative (optimal choice), a forward-slash line and the back-slash line orientation appear at 20/80. Both of these stimuli are reinforced on half of the trials.

Procedure

Pre-Training: Possums were initially exposed to a continuous schedule of reinforcement (CRF), where each of the five stimuli was randomly presented on 48 trials. A single press to the correct lever resulted in a 3s access to reinforcement; this was followed by a 10s ITI before the next trial began. Once the possums were reliably responding on the CRF they were then moved on to a Fixed Interval 10 s (FI 10s) schedule. During the FI10 the first response after a 10s time interval of the stimuli presentation gave the possum 3s access to reinforcement, this was followed by a 10 s ITI before the next trial began. Once possums responded consistently they were moved on to the first condition of the experiment.

Part One

Table 1 shows the probability of reinforcement for each of the conditions in part one of this experiment (Conditions 1-7). The table shows the probability of the stimuli appearing, the probability of reinforcement for each of the stimuli and the overall probability of reinforcement of each alternative for each of the conditions.

Condition 1/Training: Figure 7 outlines the procedure in Condition 1. During this condition the stimuli on both alternatives appeared at a rate of 20/80. The right alternative both of these stimuli were reinforced on half of the occasions, and had no associated discriminative stimulus (50/50). On the left alternative, when the vertical stimulus appeared it was reinforced with a probability of 0.13, and when the horizontal stimulus appeared it was reinforced on half of the trials (13/50).

Table 1.

Probabilities of reinforcement for Part One of this experiment (Conditions 1-7).

	Left Alternative					Right Alternative				
Condition	Probability of Presentation		Probability of Reinforcement		Overall Probability of Reinforcement	Probability of Presentation		Probability of Reinforcement		Overall Probability of Reinforcement
	—	|	—	|		/	\	/	\	
1	0.2	0.8	0.5	0.13	0.2	0.2	0.8	0.5	0.5	0.5
2	0.2	0.8	1	0	0.2	0.2	0.8	0.5	0.5	0.5
3	0.2	0.8	0.5	0.5	0.5	0.2	0.8	0.5	0.5	0.5
4	0.2	0.8	1	0	0.2	0.2	0.8	0.5	0.5	0.5
5	0.2	0.8	0.5	0.5	0.5	0.2	0.8	0.5	0.5	0.5
6	0.2	0.8	0.5	0.5	0.5	0.2	0.8	1	0	0.2
7	0.2	0.8	1	0	0.2	0.2	0.8	0.5	0.5	0.5

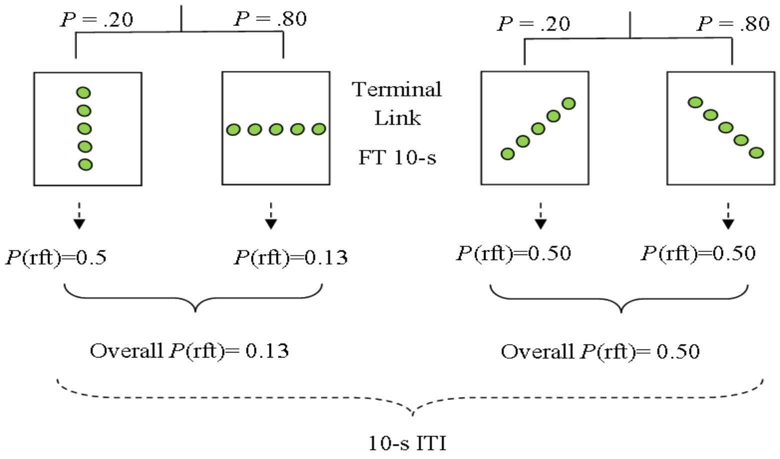

Figure 7: Illustration of Condition 1.

Condition 2: Figure 8 shows that Condition 2 continued to have the same probabilities of stimuli appearing (20/80). Figure 8 also shows that the right alternative continued to have the same probabilities of reinforcement, now termed the optimal choice (50/50). While on the left alternative the horizontal stimuli produced reinforcement on every trial, and the vertical stimuli signalled no reinforcement, therefore being a discriminative stimulus alternative and the suboptimal choice (100/0).

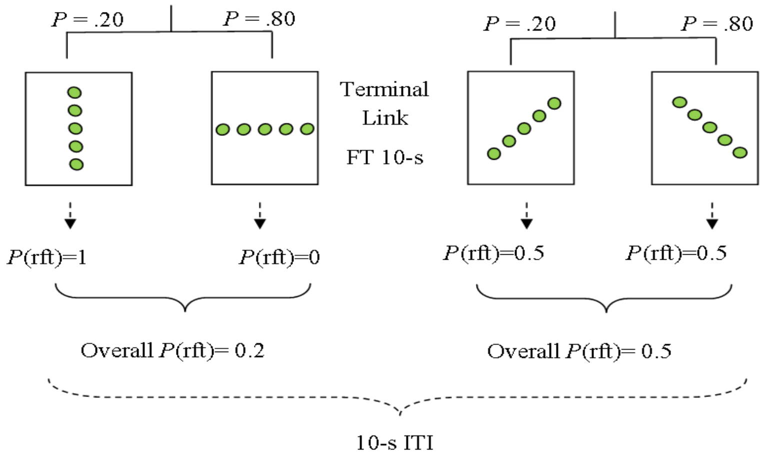

Figure 8: Illustration of Condition 2.

Condition 3: In Condition 3 there were no discriminative stimuli, as illustrated in Figure 9. The right alternative remained unchanged, and the probability of reinforcement on the left alternative was changed to the same as the right key, all stimuli (backslash and forward slash) were reinforced on half of the trials (50/50).

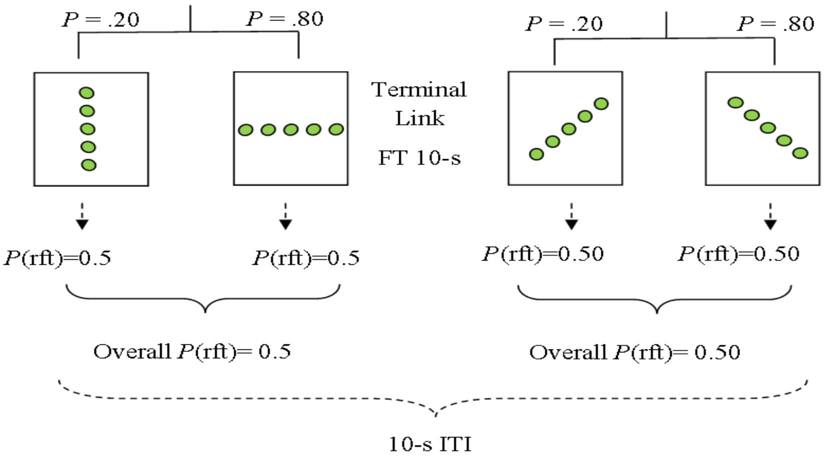

Figure 9: Illustration of Condition 3.

Condition 4: Replicated Condition 2.

Condition 5: Replicated Condition 3.

Condition 6: Figure 10 shows a swap in sides that the probabilities of reinforcement were associated with; it also shows that the stimuli remained on the same alternatives. Figure 10 shows the suboptimal choice 100/0 reinforcement rates were now presented on the right lever and the 50/50 reinforcement rate now associated with the left lever (50:20).

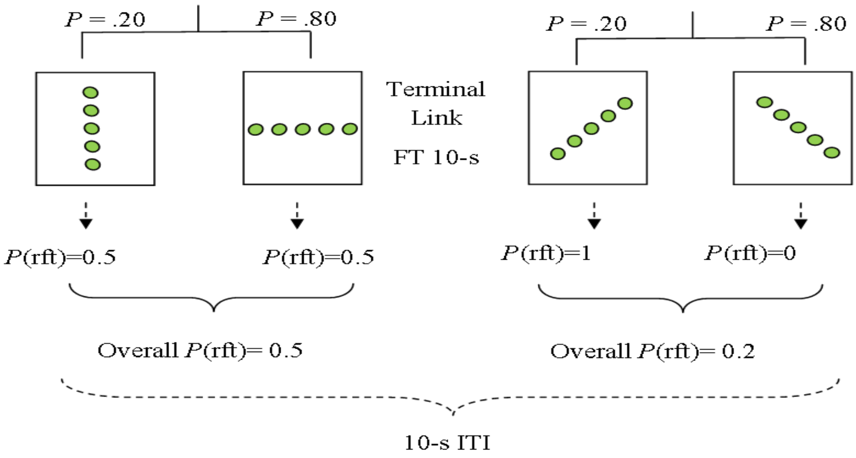

Figure 10: Illustration of Condition 6.

Condition 7: Replicated Condition 2

Part Two

Table 2 presents the probability of reinforcement for each of the conditions in Part Two of this experiment (Conditions 8-11). It shows the probability that the stimuli appear in each of the conditions, the probability of reinforcement for each of the stimuli as well as the overall probability of reinforcement for each alternative.

Condition 8: This condition replicated experiment two of Gipson et al. (2009) and ran the same as described above, with changes to the probability of stimuli appearing and the probability of reinforcement, as illustrated in Figure 11. In this condition, the probability of stimuli appearing was now 0.5 for all stimuli (50/50). The suboptimal choice, left alternative, remained being reinforced at a rate of 100/0, giving an overall probability of reinforcement of 0.5. The probability of reinforcement on the right alternative was changed to 0.75 on both stimuli, thus having an overall reinforcement rate of 0.75 on the optimal alternative (50:75).

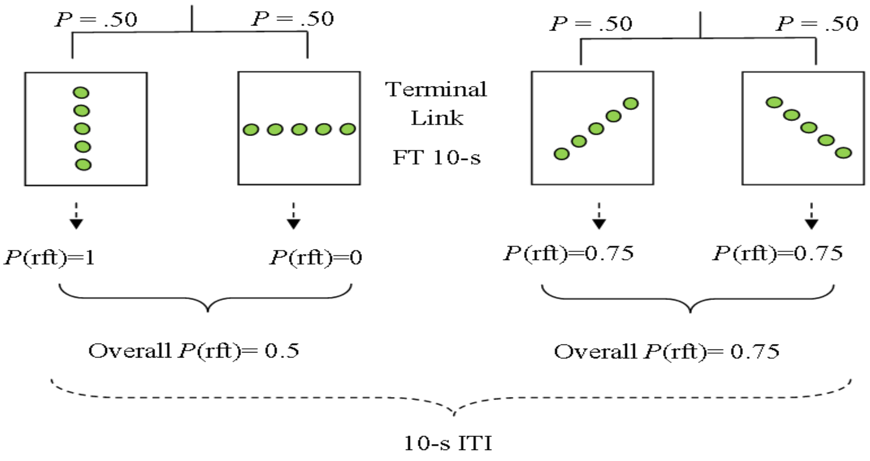

Figure 11: Illustration of Condition 8.

Table 2.

Probabilities of reiforcment for Part Two of this experiment (Conditions 8-11).

	Left Alternative					Right Alternative				
Condition	Probability of Presentation		Probability of Reinforcement		Overall Probability of Reinforcement	Probability of Presentation		Probability of Reinforcement		Overall Probability of Reinforcement
	—	|	—	|		/	\	/	\	
8	0.5	0.5	1	0	0.5	0.5	0.5	0.75	0.75	0.75
9	0.2	0.8	1	0	0.2	0.5	0.5	1	0	0.5
10	0.5	0.5	1	0	0.5	0.2	0.8	1	0	0.2
11	0.5	0.5	1	0	0.5	0.5	0.5	0.75	0.75	0.75

Condition 9: This condition replicated Stagner et al. (2012). As shown in Figure 12, the probabilities associated with the left stimuli were changed back to the original Stagner and Zentall (2010) suboptimal choice probabilities (20/80 presentation, 100/0 reinforcement). Additionally, the right probabilities were changed to the probabilities of the suboptimal choice in the previous condition (Gipson et al., 2009 replication). Thus an overall probability of reinforcement of 20:80

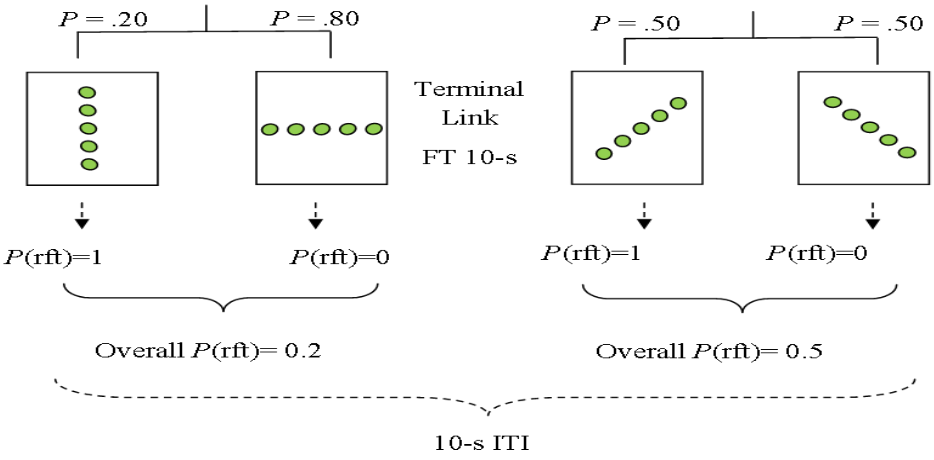

Figure 12: Illustration of Condition 9.

Condition 10: Reversed the probabilities of reinforcement in Condition 9, as illustrated in Figure 13.

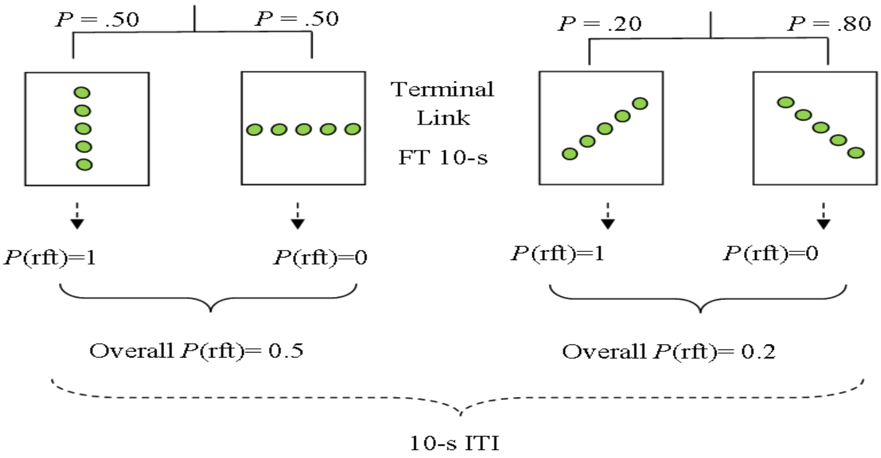

Figure 13: Illustration of Condition 10.

Condition 11: Replicated Condition 8.

Data Analysis

The data (Excel file) for this experiment can be seen in Appendix C located on the CD at the end of this document. The data file includes data collected from the sessions as well as calculations used in the analysis below. Data was removed from analysis when there were problems with or during the session. Such problems included when possums escaped from their chamber during the session which in turn would affect the responding of other possums, equipment failure inclusive of running errors and when the minimum required trials were not completed (10 trials). These data points were removed, as it was not considered reliable data because of the running errors, or that there were too little trials completed to provide a reliable estimate of the choices. Data was analysed using Excel and graphed using the graphing software Sigma plot.

The beginning of this experiment had a false start due to a slight programming error, possums had been exposed to the beginning phases (CRF and FI) and Conditions 1 and 2 before the programming error was identified and those data are not reported. All possums returned to the training component of this experiment (Condition 1) when the programming error was corrected operational. Data collected from the false start are shown in the Excel file in Appendix C.

Monkey died during the initial training phase of the experiment (during pre-training conditions), so Taylor was used in her place. Peppi began the experiment and died during the third condition and his data are not reported as they are incomplete. Both possums died due to intestinal problems common among possums held in captivity (see Signal, Foster, Temple & Chandler, 2005).

Results

Part One: Percentage Choice for the Left Alternative

Figure 14 shows the percentage choice for the left alternative for Conditions 1-7 that replicated Stagner and Zentall's (2010) study. The percentage choice for the left alternative was calculated by dividing the number of responses made on the left alternative key by the total responses made on the sum of choice on both alternatives; this was then multiplied by 100 to get a percentage. These figures are expressed as a percentage plotted on the graphs. The gaps in the data points reflect sessions that were removed due to errors (as discussed in Method).

Figure 15 shows the average percentage choice for the left alternative. The averages for that session were calculated by dividing the sum of percentage choice for the left lever alternative for all possums by 5 (the number of possums used in this experiment). The error bars were calculated in Excel using the data for all possums for that session, as plotted as error bars. Because of the varying number of sessions the possums completed in each of the conditions, the first and last 10 sessions were used in the average graphs. Error bars were graphed to illustrate the variation in possum's responses. The first and last 10 sessions are separated by a gap to show the break in the data.

Figure 14 shows that under the condition where there was a low probability alternative on the left (13/50; probability of stimuli presentation) and a high probability on the right (50/50), three possums almost exclusively selected the optimal choice (right) alternative, one was biased to the left and one were indifferent. The averages illustrated in Figure 15 reflect an overall preference for the right alternative with the error bars showing the variation in the possum's choice.

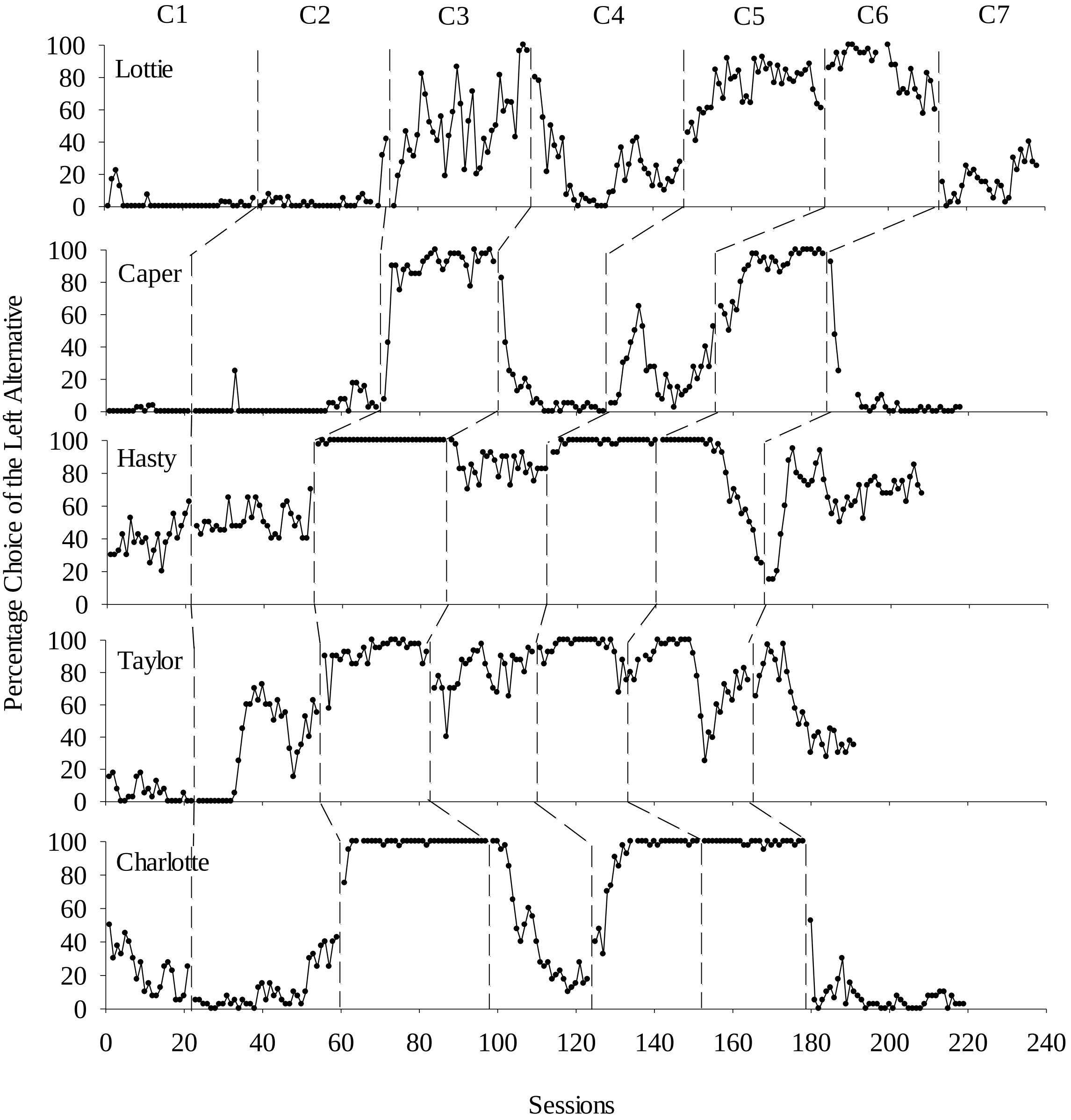

Figure 14: The percentage choice for the left lever alternative for part one of this experiment (Conditions 1-7) for each of the possums. Dashed lines represent a new condition. Gaps in the data line show a session that was removed due to the sessions having less than 10 trials completed.

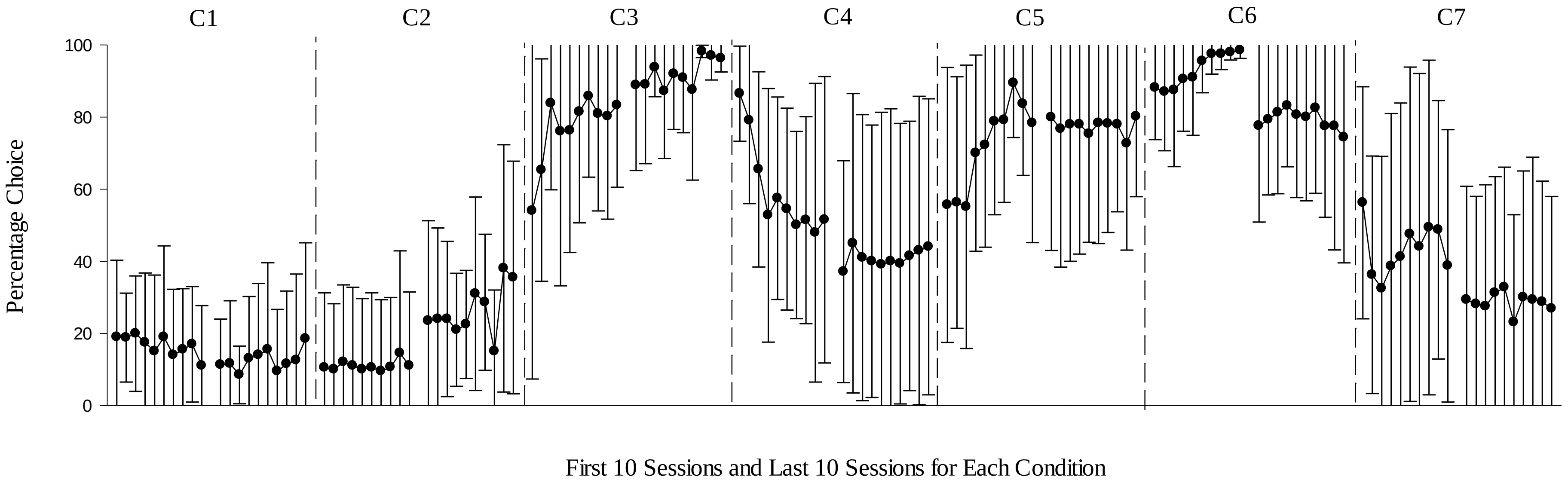

Figure 15: The averaged percentage choice for the left alternative for part one of this experiment (Conditions 1-7) with error bars. The first 10 and last 10 sessions of each condition were used because of the difference in the number of sessions completed by each of the possums.

When the probabilities changed to 100/0 on the left, and 50/50 on the right (replicating Stagner & Zentall, 2010; 50:50), Figure 14 shows that the two possums who were previously extreme in their choosing continued to choose the right, now optimal alternative. Both possums had further variation in their data by the end of the condition. Hasty, who was indifferent in Condition 1, continued to be indifferent during Condition 2. Taylor and Charlotte began the condition with a preference for the right alternative, which adjusted towards the left alternative; both were choosing each alterative 50% of the time by the end of Condition 2. The averages in Figure 15 show an overall preference for the right alternative (optimal choice), the jump in averages in the last 10 sessions reflects the changes towards 50/50 for three possums towards the end of the condition.

In Condition 3 there were no suboptimal choices. Both alternatives were changed so that the probabilities were equal on both sides (50:50). Figure 14 shows that during this condition two possums were choosing the left lever exclusively, two had a left bias and one possum was indifferent. Figure 15 shows an average overall left preference which was seen in four of the possums during Condition 3.

Condition 4 replicated Condition 2, where the low probability alternative was on the left alternative and the right was the high probability alternative (20:50). Individual data, displayed in Figure 14, show two possums with a preference for the right alternative (optimal choice), two possums with a preference for the left alternative (suboptimal choice) and one possum who started the condition with a preference for the left which changed to the right as the condition progressed. Figure 15, show that when averaged, there is a decreasing trend in choice for the left alternative; this reflects two of the possum's choices. However a larger error bar shows the large variance across possums.

Condition 5 repeated Condition 3, where probabilities were equal (50:50). Figure 14 shows three possums with a left bias, one possum who was indifferent and the other with a slight right bias. The average data, in Figure 15, shows an increase in preference in the first 10 sessions for the left alternative as seen in two of the possums. This stabilised in the last 10 sessions, however, still showing a slight preference for the left alternative.

Condition 6 reversed the previous suboptimal conditions (Conditions 2 and 4) so that the suboptimal alternative was now on the right lever and the left alternative was now the optimal choice (50:20). In Figure 14, the individual possum data shows that three of the possums had a preference for the left alternative (optimal choice); these were same three possums' that had chosen the optimal alternatives in previous conditions. One possum who was indifferent and the other began the condition choosing the left alternative (optimal) and their preference switched towards the right (suboptimal alterative) as the condition progressed. Averaged data shown in Figure 15 shows an increase in preference within the first 10 sessions for the left alternative, with very small error bars showing that it was the trend of all possums. The sharp decline in the averaged data of the last 10 sessions illustrates the reduction in preference for the left alternative shown in three possums (Lottie, Hasty and Taylor).

Condition 7 was the final replication of Stagner and Zentall's (2010) experiment, this condition repeated Condition 2 and 4 where the left alternative was the suboptimal choice and the right was the optimal (20:50). Individual possum data in Figure 14 shows two possums with a strong bias for the right alternative and one possum with a slight bias for the right. Two possums show a large variation in their preferences. Averaged data show the large variance in the possums responding through the larger error bars. Overall the averaged data, in Figure 15, show a marginal preference for the right alternative (the optimal choice).

During the replication conditions (Condition 2, 4 and 7), all possums are consistent in their choosing, that is all possums continued to show a preference for the same alternative. These choices are consistent in the reversal conditions, except for Taylor who is indifferent and Hasty who took longer to make the switch from optimal to suboptimal.

Part Two: Percentage Choice for the Left Alternative

Figure 16 shows the percentage choice for the left alternative for each of the possums for Conditions 8 to 11. These are presented in the same way as they were in Figure 14. Figure 17 shows the averaged data with error bars for Condition 8 to 11, in the same format as displayed in Figure 15.

Condition 8 replicated Gipson et al.'s (2009) condition where the probability of stimuli presentations was changed to 50%. In this condition the low probability alternative was on the left and the high probability on the right (50:75). Figure 16 shows that two of the possums had an extreme preference for the left alternative (suboptimal choice) and the other three had increasing preferences for the left alternative. The averaged data, in Figure 17, reflects the increasing preference for the left alternative shown by three of the possums.

Condition 9 replicated one of Stagner et al.'s (2012), where the probabilities of the stimuli presentations were changed to 20/80 for the left (suboptimal) alternative and 50/50 on the right (optimal) alternative. The

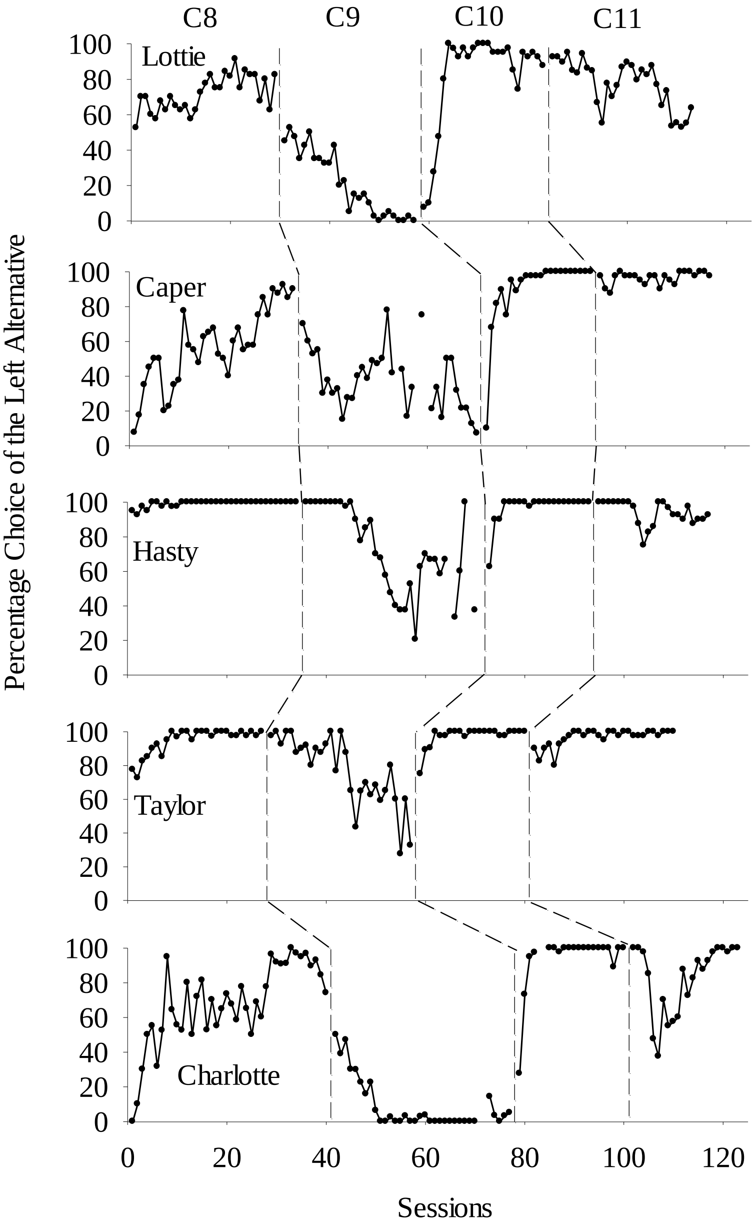

Figure 16: The percentage choice for the left lever alternative for part one of this experiment (Conditions 8-11) for each of the possums. Dashed lines represent a new condition. Gaps in the data line show a session that was removed due to the sessions having less than 10 trials completed.

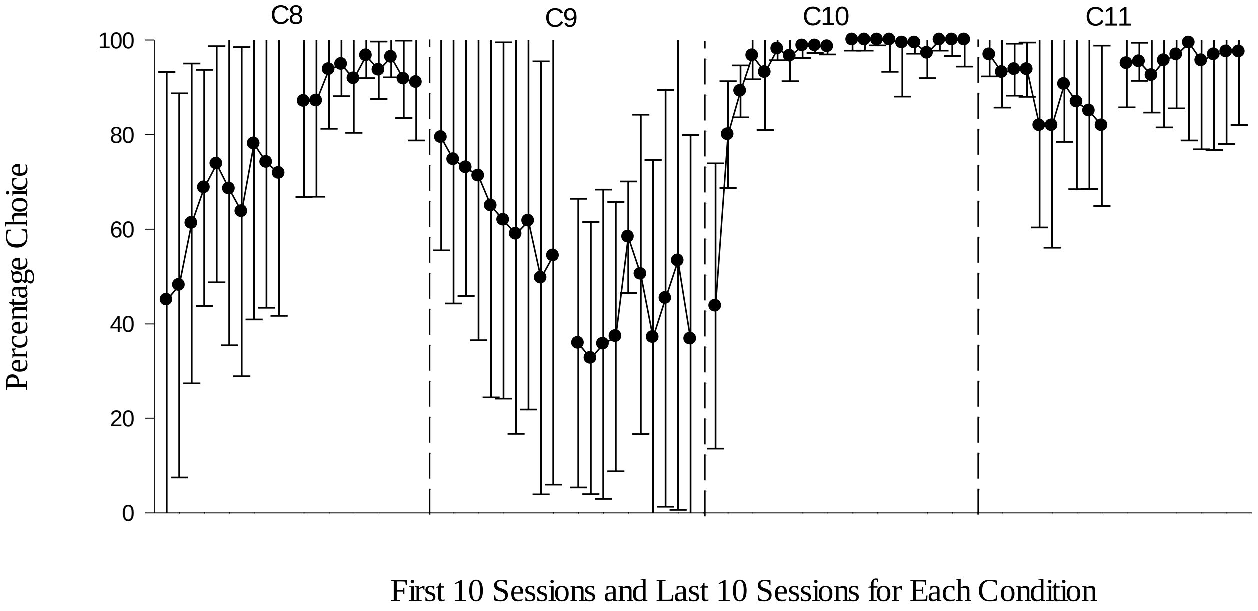

Figure 17: The averaged percentage choice for the left alternative for part one of this experiment (Conditions 8-11) with error bars. The first 10 and last 10 sessions of each condition were used because of the difference in the number of sessions completed by each of the possums.

probabilities of reinforcement for both alternatives were 100/0, there for with an overall probability of reinforcement of 20:50. Figure 16 show two possums with a preference that increased for the right alternative (optimal), two possums were indifferent, and the final possum was also indifferent. Averaged data reflects the large variation in possums responding, shown in the larger error bars. Overall, the trend of the averaged data shows a decrease of preference for the left alternative.

Condition 10 reversed Condition 9, thus the low probability alternative (suboptimal choice) was now on the right alternative and the high probability alternative (optimal choice) on the left (50:20). This condition showed all possums with a preference for the left alternative, now the optimal choice, illustrated in Figure 16. Averaged data in Figure 17 reflects this overall trend with smaller error bars.

The final condition (Condition 11), replicated Condition 8, where the left alternative was the suboptimal choice and the right the optimal choice (50:75). Individual data in Figure 16 shows possums responded in a similar way to Condition 8, three possums showed strong preference for the left alternative. One possum was more indifferent and the other decreased their preference for the left alternative before increasing again. Figure 17 shows that on average there was an overall decrease in preference in the first 10 sessions; this follows the pattern from two of the possums responding in those sessions. The final 10 sessions show an overall preference for the left alternative (suboptimal choice) which is shown by the majority of the possums in those sessions.

Percentage Choice for the Suboptimal Alternative

Figure 18 shows the graphed data for all conditions in which there were suboptimal alternatives available. The data is graphed as percentage choice for the suboptimal option, that is, responding at the 100% mark represents a suboptimal choice and 0% represents an optimal choice. Gaps in the data paths reflect sessions that were removed as previous figures. Figure 19 shows the graphed averaged data for all of the conditions where there was a suboptimal alternative present, as in Figure 18 and previous averaged graphs.

Three possums in the Stagner and Zentall (2010) suboptimal conditions (Conditions 2, 4, 6 and 7) showed a preference for the optimal alternative and the other two possums showed a preference for the suboptimal choice, as shown in Figure 18. Averages presented in Figure 19, shows that across the Stagner and Zentall (2010) replication conditions, on average there was a preference for the optimal alternative. Error bars across these conditions were large; this is due to the varied preferences across possums seen in Figure 18.

When the probabilities changed in the Gipson et al. (2009; Condition 8 and 9), on average the possums had a preference for the suboptimal alternative as seen in Figure 19. In the first replication the averaged data showed an increasing trend toward the suboptimal alternative which became more stable in the last 10 sessions and in the replication (Condition 11). In the first replication (Condition 8) three possums increased their preference for the suboptimal alternative, which was reflected in the averaged data. When this condition was replicated in Condition 11, three possums continued to show a preference for the suboptimal alternative, with one showing more variation, shown in Figure 18.

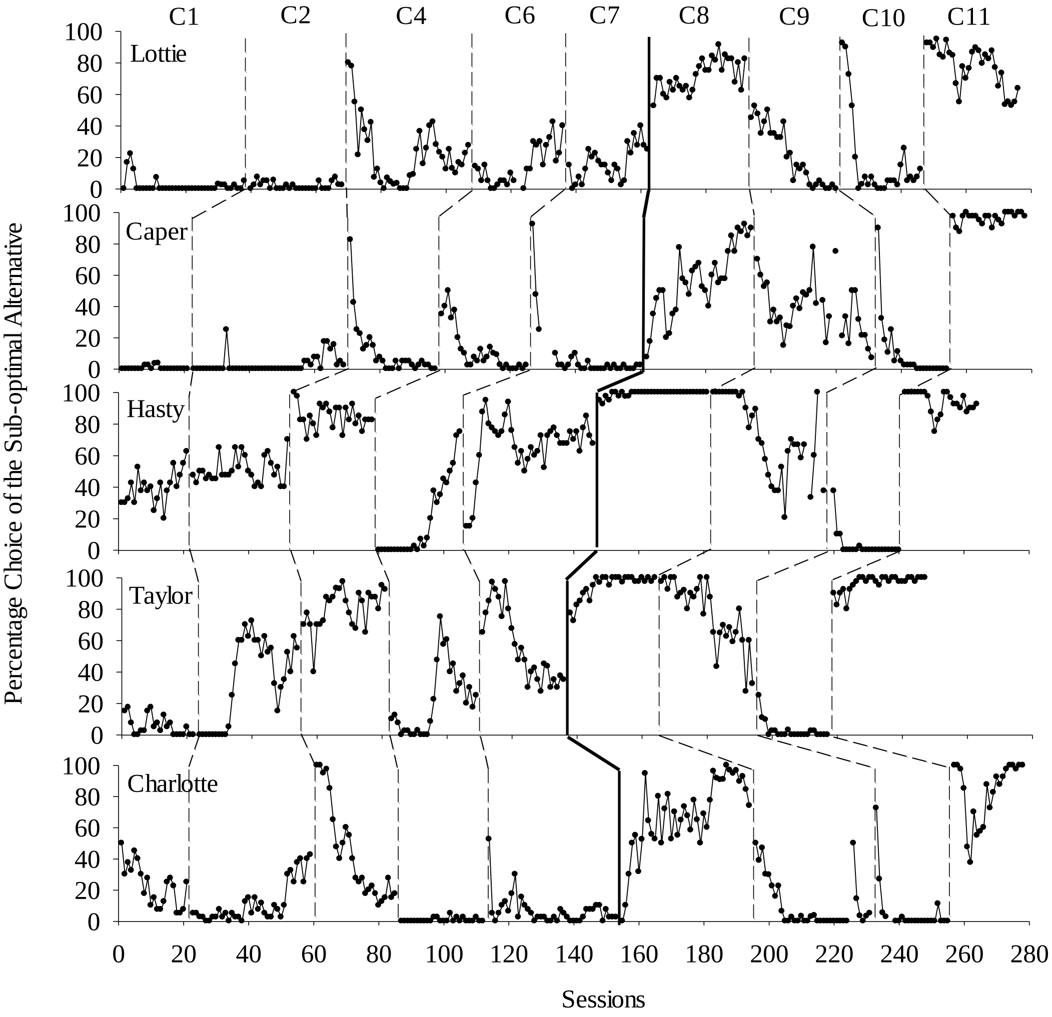

Figure 18: The percentage choice for the suboptimal alternative for each of the possums. Conditions shown in this graph are only conditions where there is a suboptimal choice (Conditions 3 and 5 removed). Dashed lines represent a new condition. Gaps in the data line show a session that was removed due to the sessions having less than 10 trials completed.

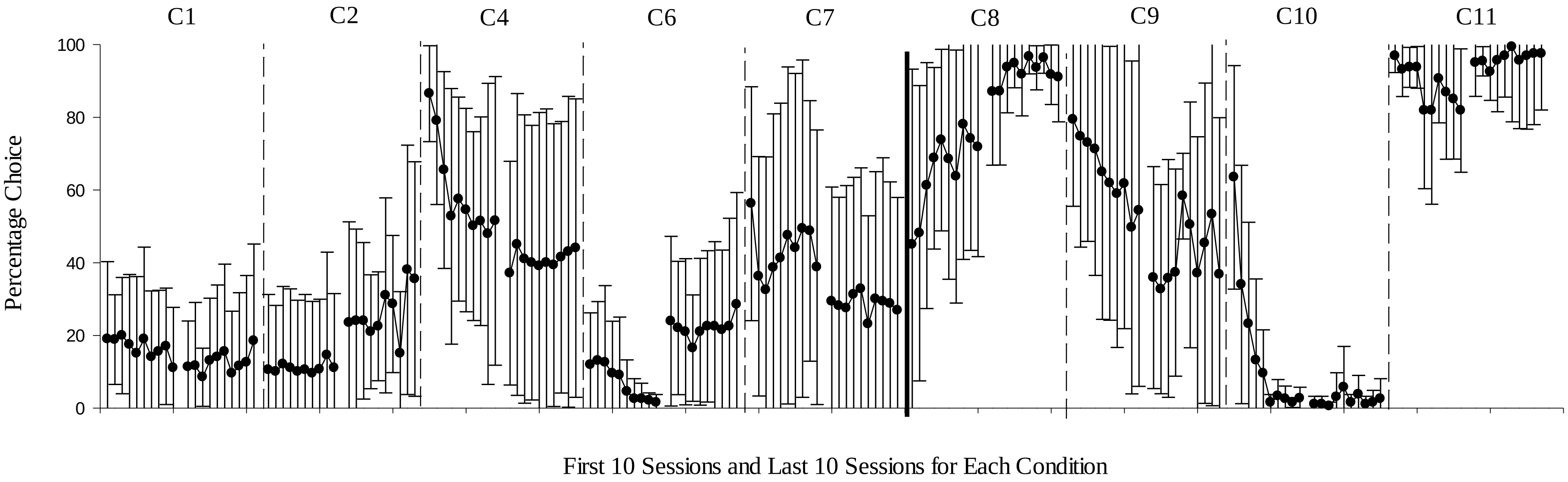

Figure 19: The averaged percentage choice for the suboptimal choice with error bars. The first 10 and last 10 sessions of each condition were used because of the difference in the number of sessions completed by each of the possums.

Stagner, Laude and Zentall's (2012) replication (Condition 9 and 10) showed that two possums had an optimal choice preference, one possum showed a variation in responding, and the other two initially showed preferences for the suboptimal alternative which switched to the optimal choice as the conditions progressed. Averaged data shows that overall possums in the initial replication were indifferent with very large error bars, reflecting the variation in individual data. In the reversal of this condition the averaged data reflected a preference for the optimal alternative with smaller error bars, showing this preference among all possums.

Weights

Weight data was collected and graphed during the experimental period. As discussed in the method, possums were weighed weekly to maintain their weight. Appendix B shows the possums weights across the experimental period. The round data points connected with lines represent the possums recorded weights in grams, while the lines show the amount of post-feed (grams). Possums had a target weight, this is represented by the horizontal line on the graph, and either side of this are dashed lines that show the ideal weight range (+/- 5% of the target weight).

These graphs show that all possums were kept within their weight range during the experimental period. It also shows that there are no consistent differences amongst possums.

Discussion

The purpose of this study was to determine if possums, like pigeons, would choose an alternative with a low probability of reinforcement that produced discriminative stimuli over an alternative that did not produce stimuli but was associated with a higher probability of reinforcement. It was initially expected that the possums would make the same suboptimal choices. On the contrary, overall the majority of the possums did not show this preference. However this aligns with more recent studies with rats.

The first part of this experiment replicated Stagner and Zentall's (2010) procedure where the probability of stimuli presentation was 20/80 with the discriminative stimuli on the left alternative (100/0 reinforcement ratio) and none on the right alternative (50/50 reinforcement ratio). During these conditions three possums showed a preference for the optimal alternative (50/50), while two had a preference for the suboptimal alternative (100/0). These preferences in responding were found to be reliable over the three replications of this procedure as well as in the reversal, seen in Figure 14. Thus the initial expectation that all possums would choose suboptimally was not confirmed.

Stagner and Zentall (2010) only provide averaged data so it is not possible to see if any of the animals are optimal. Trujano and Orduña's (2015) also provided averaged data of rats' preferences; however, they included error bars showing a small variation in possum responses. Error bars were presented in later studies with pigeons (see: Laude et al., 2012; Laude et al. 2014; Pattison et al., 2013; Zentall et al., 2015; Zentall & Stagner, 2011a; and Zentall & Stagner, 2011b), again showing a smaller amount of variation. When comparing the recent studies average graphs, Figure 19, shows an overall preference for the optimal alternative across all replications and the reversal, consistent with the rats findings. Figure 19 shows a large error bars, illustrating the large variation in possums responding. When the variation has been previously reported, it has not been as large as found with possums.

Ngatai (2013) and Yang (2015) using the same procedure as Stagner and Zentall (201) presented individual data. Ngatai (2013) reported that while over these conditions and their replications, the hens mostly chose the suboptimal alternative, two of the six pigeons did not consistently choose it in all conditions. Yang (2015) also found that four of the six roosters showed a preference for the suboptimal alternative. Therefore, individual data conveys the variation in preferences more accurately than in averaged data.

Unlike Stagner and Zentall’s (2010) pigeons and Ngatai’s (2013) hens, the possums in this experiment showed an averaged preference for the optimal alternative. This overall preference of an optimal alternative is also seen with rats in Trujano and Orduña (2015) experiment, suggesting that there are some similarities in rodent and marsupial behaviour. Additionally, an overall optimal preference has been seen in early concurrent-chain procedure with different probabilities of reinforcement (see: Fantino et al., 1979; Kendall, 1985; and Mazur, 1996).

To break up the Stanger and Zentall (2010) replication conditions and to provide a contingency where there were no discriminative stimuli, possums were exposed to a condition where there were equal probabilities on both alternatives. It was expected that in these conditions the possums would show indifference and not show a side bias as Ngatai (2013) and Trujano and Orduña, (2015) had found.

This was not the case, all possums showed a side preference during these conditions, some had a strong side bias across the replications. On reflection, it seems unsurprising that the possums had a side preference in these conditions. The initial links in these conditions were both a FR1, there was the same inter-trial interval (FT10s) and the reinforcer amount was the same on both alternatives, there was no benefit in selecting both alternatives. More generally, concurrent-chain procedures use variable interval initial link schedules so while selecting one entry the other becomes more likely. So animals might be expected to respond on both. As pointed out that is not so when the initial links are FRs. So possibly the data of Ngatai (2013) and Trujano and Orduña, (2015) are the more surprising findings and not that of possums. Therefore when possums are choosing one alternative they are more likely to optimise their food, this supports the 'Law of Least Effort' in that continuing to choose one alternative requires the least amount of effort to get the same amount of reinforcement.

The second part of this experiment began by replicating a part of Gipson et al.'s (2009) study. The probability of the stimuli appearing was changed to 50/50 as well as the probability of reinforcement associated with the optimal alternative increased from 50% to 75%. The suboptimal alternative remained reinforcing at a rate of 100/0. Having an overall probability of reinforcement of 50% on the right alternative and 75% on the left. Initially it was expected that the data from possums would replicate that of Gipson et al.'s (2009). However, because the possums had not responded as expected in the Stagner and Zentall (2010) replication, it could be expected that they might continue their previous preference of an optimal or suboptimal choice. Under these outcomes all possums showed a preference for the suboptimal alternative in both conditions. This was what

Gipson et al. (2009) reported he noted that the majority of the pigeons (13 of 16) showed a preference for the suboptimal alternative (50% reinforcement). While the differences in animal preference are consistent with Part One of this experiment, is not consistent in possums during the replication of this procedure. These are the only data in this experiment that were consistent with pigeon data.

In these replications possums were selecting the suboptimal alternatives (50% reinforcement) and so behaving in a way that suggests that the suboptimal alternative (50%) had the better outcome. This could be attributed to the uncertainty of the outcome on the optimal alternative (75% reinforcement). The suboptimal alternative (the 50% reinforcement rate) had the discriminative stimuli and given the outcome of the stimuli was always reinforced on half of the trials and the other stimuli never on the other half, thus it became certain that when that stimulus was present so would a reinforcer.

In the next condition the probabilities of reinforcement and stimuli presentation were changed to those used by Stagner et al. (2012). The previously used suboptimal alternative (those used by Stagner and Zentall, 2010), was again the suboptimal alternative (20/80 probabilities of presentation). From the previous conditions (Gipson et al, 2009 replication) the suboptimal alternative now the optimal choice (50/50 probability of presentation). So the possums were choosing between alternatives that both had discriminative stimuli (100/0 probability of stimuli presentation).the overall reinforcement rate on the left alternative was 20% and 50% on the right. Stagner et al. (2012) reported that under these conditions pigeons were indifferent in their choosing, thus the same was expected of possums. Here under this condition possums showed either indifference or a preference trending towards the optimal alternative (50/50).

In this condition, possums had the choice between two alternatives that signalled reinforcement (100/0 probability of reinforcement), one that occurred on 50% on the trials and the other on 20% of the trials. Under these probabilities, possums were found to choose the 50% alternative, which had the more reliable outcome of producing reinforcement. This supports information theory, in that possums are more likely to choose an outcome that reliably provides reinforcement as informed by the stimulus.

In the training component, where the rate of reinforcement on the left alternative was suboptimal was a probability of reinforcement of 50/13, while the right was optimal (50/50). Neither of the alternatives had associating discriminative stimuli. Optimal foraging theory might predict that the possums would choose the alternative that provided more food. Three possums showed a preference for the alternative that provided more food and two were indifferent.

In sum, the data from the replication of Stagner and Zentall (2010) and Stagner et al. (2012) replications showed that the majority of possums were optimising their food intake. The data provides evidence for optimal foraging theory (Stephens & Krebs, 1986), as discussed earlier, where an animal will make a choice or act in a way that will maximise their food intake.

Possums are characterised as being foragers in the wild, this could account for the overall preference for the optimal alternative, seen in three of the possums in the initial replication. As the possums want to maximise their food intake by nature, as in the wild they will not be sure of when they can next have food available. These preferences also support ‘the law of effect’ which assumes that animals will choose the alternative that leads to the most amount of reinforcement. However, this is not provide evidence for all possums in all conditions, as some of the possums were choosing suboptimally during these same conditions and then all switched in the Gipson et al (2009) replication conditions.

Conditioned reinforcement theory holds that animals will make a choice for an alternative that has been reinforcing in the past. In addition, information theory states that an animal is more likely to choose an option is more certain (i.e. the discriminative stimulus; Dinsmoor, 1983). The data from the Gipson et al. (2009) replication conditions where the discriminative stimulus probability of reinforcement was higher than had been in previous conditions and in those from the Stagner, Laude and Zentall (2012) replication condition where both alternatives had discriminative stimuli, conditioned reinforcement theory was supported. The data from the replication of Stagner and Zentall (2010) with the possums that were choosing the suboptimal alternative under these contingencies, also support this, the others do not. Of the 40 conditions (across five possums) that provided a suboptimal alternative with a discriminative stimulus, it is seen that the majority of the conditions (28 of the 40) reported a preference for the suboptimal alternative. Therefore for these conditions it is perceived that the suboptimal alternative with the more beneficial outcome, supporting conditioned reinforcement theory and information theory.

In order to determine if possums showed a preference for the reliable outcome with discriminative stimuli, it will be useful to use the Gipson et al. (2009) without the discriminative stimuli. This would show if they would continue to select the suboptimal alternative or if they would switch to the optimal alternative. This change in preference has been seen in other studies it has been seen when the discriminative aspect of the stimulus is removed (e.g. Stagner & Zentall, 2010; Stagner & Zentall 2011; and Zentall & Stagner, 2011a). A preference for an optimal alternative when there were no discriminative stimuli was also seen in the initial training phase of this experiment for four possums, however only three continued to choose this optimally with the presence of a discriminative stimuli. Therefore it is not clear to how possums will behave under these circumstances and more research in the area is needed.

Weight Control

It was speculated with pigeons that restrictions to diets may affect choice, as seen in previous experiments (Laude, Pattison & Zentall, 2012). Because of this, it was questioned if these restrictions had an effect on the possums responding. The weights of the possums, in Appendix B, show that all possums were in all within their weight range (+/- 5% of their target weight) throughout the entire experiment. Therefore, it can be concluded that it was not the weight specifically that has gave rise to suboptimal choosing, and that a change in preference for the suboptimal choice was not associated with an increase or decrease in supplemented food.

Limitations

It could be suggested that using different stimuli used from those used in the original studies could have resulted in the difference of possums preferences compared to pigeons. Due to not being certain possums would able to distinguish between red/green and blue/yellow stimuli as used with pigeons it was decided to use line orientation stimuli, as discussed earlier. Possums are able to distinguish between horizontal and vertical line orientations in a previous experiment (Hardaker, 2006) thus were selected for use here. Possums were seen to be under the control of the discriminative stimuli in some conditions. Thus, it is unlikely that this change in stimuli contributed to the preference differences in possums, as the purpose of this study was to investigate possum's responses to different probabilities of reinforcement rather than the different stimuli.

Non-completion of all trials in a session posed a problem. As noted earlier, not all sessions were completed as a result of the possums not working and returning to their nest boxes. One explanation for this was the possums' lack of food motivation that is of reinforcer effectiveness. During the final conditions of this experiment three possums, Caper, Hasty and Charlotte, were not completing all of their trials in each session. Therefore a decision was made to change their reinforcer to Extruded Maize, which had been shown to be an effective reinforcer in other suboptimal choice experiments with possums running at the same time (Bremner, 2016; and Hancox, 2016). Once the possums were switched to this reinforcer their responding increased and they completed sessions (see Figure 16 and 18). This change in reinforcer did not have an impact of their preference but did on their session completion. This is specifically seen in the replication of Stagner et al. (2012; Condition 8 and 10) where responding was consistent across both of these replications, variation in responding reduced in Condition 10 where the new reinforcer was used. The Gipson et al. (2009) replications also saw less s variation where the new reinforce was implemented, as seen in the error bars in Figure 19. This suggests that the only effects the change in reinforcer had on the possums' preferences was to increase motivation and stabilise behaviour. .

Possums' behaviour was generally variable and thus it was difficult to judge stability. The possums' choice sometimes changed so rapidly, that while for a short period the preference would appear to be stable, it then would change to a new level. Because of this sudden change it was difficult to determine stability. In order to reduce this, a change to the more effective reinforcer (extruded maize) might have reduced the variability in responding (as noted above) as it is seen in Part Two of this experiment when variation decreased. .

Initially, it was planned that the possums would complete 20 sessions or 2400 trials in each condition before progressing. However, in the first condition it became clear that performance was variable, so instead of finishing the condition at this point it was decided to continue until the data paths were stable to ensure that possums were responding consistently. Stability was then determined to be reached when it was observed in individual data that possums had responded consistently for at least 5 of sessions. This resulted in the different number of session for each possum. Because the criteria were changed to stable responding then it meant that some possums required longer on the condition. One reason for why it took possums longer to be stable was that it was hard to assess stability with variable data (as discussed earlier).

While it would have been easier for possums to complete the same set number of sessions as Stagner and Zentall’s (2010) did, this would have not have resulted in an accurate representation of the changes possums’ behaviour as not stable. Although for some possum basing conclusions on the first 12 sessions the same as Stagner and Zentall (2010) used, would not have changed the present conclusions in some conditions. For other conditions using the first 12 sessions would have resulted in more indifferent choosing. Thus in order to assess stable behaviour a longer number of sessions was supported by some possums responding.

To compare the present data with Stagner and Zentall’s (2010) and Stagner et al. (2012) the average data was also presented in this study, as they had done so in their experiments. As there were variation in the number of sessions that a number of possums completed in each condition and to allow for easier comparison of performance across the different conditions it was decided to average the data. Data was averaged over the first 10 sessions and last 10 sessions of each condition, as described in the results.

There was a false start to this experiment as described in the method, where there was a small error in the original programme. It was decided to re-start the experiment from the training session again as different possums were at different points in the conditions when this was identified, this meant that not all possums had started Conation 2. Their responding at the start of the training condition was impacted by the previous incorrect conditions. It may have been better to replicate the pre-training (CRF and FI10) to assure consistency in our data

Conclusions

Human gambling has been researched using animal models, in particular concurrent-chain procedures to investigate suboptimal choice. Overall the subjects of the current experiment had an initial preference for the optimal alternative. This was different to the averaged findings by Stagner and Zentall (2010). This overall preference for the optimal alternative supports optimal foraging theory and the law of effect, as possums by nature are foragers and thus were maximising their food intake. An overall preference for the optimal alternative also supports Trujano and Orduña (2015) findings with rats. Since the completion of this thesis two further possum studies (Bremner, 2016; and Hancox, 2016) have also found an overall suboptimal choice preference, with slight variations among possums.

However, this finding was not consistent amongst all possums and in all Part One. Two possums were selecting the suboptimal choice, variation between subject's shows that at times possums were not maximising their gains, but selecting the more reliable alternative. This then suggests for these possums that the presence of discriminative stimuli made reinforcement less uncertain and thus appeared to be the favourable outcome. Part To of this experiment shows possums choosing the discriminative stimuli that were associated with a more reliable outcome. Conditioning and discriminative stimuli has been suggested as a mechanism for suboptimal choosing in previous studies.

This study adds to the previous research in that it supports non-avian research by Trujano and Orduña (2015) who found an optimal preference in rats and earlier studies with pigeons (Fantino et al., 1979; Kendall, 1985; and Mazur, 1996)., it also adds to previous research that shows a different outcome for different subjects for this procedure (Laude et al., 2012; Laude et al. 2014; Pattison et al., 2013; Zentall et al., 2015; Zentall & Stagner, 2011a; and Zentall & Stagner, 2011b).

The results of this study show that there are differences in the way that possums respond to a suboptimal choice procedure in comparison to previous studies with pigeons. Further investigations into possum preference on this suboptimal choice procedure would help to identify the mechanisms behind these choices.

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