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Sub-Optimal Choice Behaviour

by Possums

A thesis

submitted in partial fulfilment

of the requirements for the degree

of

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Abstract

This study aimed to investigate sub-optimal choice using six brushtail possums (*Trichosurus vulpecula*). Experiment 1 replicated Zentall and Stagner's (2011) procedure where the possums were required to choose between two alternating alternatives; The low probability alternative (sub-optimal) was a discriminative stimuli signalling 3.5-s reinforcement on 20% of the trials, and non-reinforcement on 80% of the trials; the high probability alternative (optimal) was a non-discriminative stimuli signalling 1-s reinforcement 100% of the time regardless of the stimulus presented. This was unsuccessful as the possums showed a clear indifference to the alternatives.

Due to these ambiguous results, we replicated two conditions of Stagner and Zentall's (2010) procedures to achieve sub-optimal responding in possums. Experiment 2 was similar to Experiment 1, however the alternation was removed and the high probability alternative was a non-discriminative stimuli associated with 50% reinforcement regardless of the stimulus presented. Sub-optimal responding was not achieved, however the possums now showed a preference for the optimal alternative.

Alternation may have affected Experiment 1 and to examine this theory, Experiment 3 was replicated without alternation. Interestingly, we found a preference for the high probability alternative. Experiment 4 replicated Experiment 3; however the length of time for reinforcement was altered to attenuate sub-optimal responding. A preference for the high probability alternative which provided an overall greater net payoff was found. The possums changed from indifference to choosing optimally. It appears that possums do not have a preference for the sub-optimal choice the same as pigeons.

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Introduction

Gambling has been around for many centuries and has become increasingly problematic, often leading to social and family difficulties (Livingston, 2008; Lyons, 2006). Many people will gamble occasionally for social reasons or entertainment; however some of these will become addicted to gambling and have to live with the associated problems (Shaffer & Hall, 2001; Lyons, 2006). Unlike many addictions gambling does not involve consuming substances, such as alcohol or drugs, but still produces a pattern of behaviour that is like those of other addictions (Rachlin, 1990; Wagenaar, 1988).

Gambling generally involves foregoing money now for the low-probability of winning more money later (Zentall & Stagner, 2011a). Gambling often persists despite reliably producing a net loss of money (de Villers, 1977; Laude, Beckmann, Daniels, & Zentall, 2013; Skinner, 1953). In particular, gamblers are more likely to choose a low-probability but high-payoff alternative over a high-probability but low-payoff alternative; as a result over time the net return is lower than the amount expended (Molet, Miller, Laude, Kirk, Manning, & Zentall, 2012; Zentall & Stagner, 2011a; Zentall, 2014). Gambling comes in many forms; for example in casinos with slot machines, roulette, bingo and black-jack or lottery style gambling on a weekly basis. Gambling behaviour is said to be making a sub-optimal choice because continuing to gamble will always result in more losses than wins (Zentall & Stagner, 2011a; Zentall, 2014). The gamblers' behaviour is often described as impulsive and it appears that they fail to recognise the long-term consequences of their decisions given their behaviour (Nower & Blaszczynski, 2006). Research has shown that pathological gamblers seem to seek the immediate gratification that gambling provides, or at least relief from

states of deprivation, despite the long-term consequences (Yechiam, Busemeyer, Stout, & Bechara, 2005).

Experienced gamblers know that their “game of choice” pays off poorly, however the frequency of the gambling behaviour does not reduce (Zentall, 2011; Zentall & Stagner, 2011a), thus they appear to overvalue the winning outcomes and undervalue their losses (Beach & Lipshitz, 1996; Wagenaar, 1988). This bias in value could be related to the availability heuristic, which suggests that we make decisions based on the knowledge that is readily available rather than examining the alternatives (Tversky & Kahneman, 1974), or the fact that gamblers tend to consider their wins are more salient than their losses (Breen & Zuckerman, 1999; Rachlin, 1990).

Winning might also be strengthened by the social attention which is associated with most gambling venues; when there is a win the gambler is reinforced by a combination of bells ringing, flashing lights and social attention, where losses are not associated with these social effects (Breen & Zuckermann, 1999; Clark, Lawrence, Astley-Jones, & Grey, 2009; Zentall, 2011). As a result the decision to continue gambling despite increasing losses shows that gamblers fail to maximize their gains and minimize their losses (Laude et al., 2013; Molet et al., 2012; Rachlin, 1990; Zentall & Stagner, 2011a).

Other addictions often exist with use of a substance that is consumed at a high rate such as alcohol or drugs. Gamblers seem to be risk-takers; however this is not connected to a substance or internal pleasure states but more of an interaction between behaviour and the environment (Rachlin, 1990). Recently, this has led to gambling receiving substantial attention among researchers as behaviour in its own right, which is important because it is not clear how the

normal bio-chemical arguments for addiction apply to gambling (Rachlin, 1990; Wagenaar, 1988; Weatherley & Phelps, 2006). Unfortunately, experimental research on human gambling behaviour is a challenge, due to ethical concerns and the failure to replicate the contingencies from the natural gambling environment (Weatherly & Phelps, 2006). To implement a scientifically precise experiment, it is important to manipulate and control the environment that the participants experience. (Weatherly & Phelps, 2006). In addition, researchers like to be able to control the participants' previous reinforcement histories. Such control is valuable in studying gambling when using non-human subjects (Weatherly & Phelps, 2006; Zentall, 2011). Some have argued that the procedures used to examine gambling behaviour with non-human subjects is not a valid analogous of real life gambling situations (Weatherly & Phelps, 2006). However, behavioural psychologists concluded that using non-human subjects and operant procedures is analogous to real life gambling and will assist in gaining a "meaningful" understanding into behavioural mechanisms that either contribute to or discourage human gambling behaviour (Peters, Hunt & Harper, 2010; Weatherly & Derenne, 2007; Zentall, 2014).

The study of sub-optimal choice with non-human animals could be considered paradoxical due to the evolutionary studies of animal behaviour. It is assumed that animals would be less susceptible to sup-optimal choices, unlike human gamblers, since this would affect their survival. According to optimal foraging theory, animals should make optimal choices associated with procuring food as this aligns with a biological model "survival of the fittest" (MacArthur & Pianka, 1966; Stephens & Krebs, 1986). Optimal forging theory predicts that non-human subjects should maximize their gains and minimize the losses. However, human decision making studies show that the motivation for making

sub-optimal choices is complicated by cultural, social factors and reinforcers that are independent to the direct outcome of the decisions (Humphreys & Latour, 2013). This suggests that non-human animals choose optimally in an animal model of gambling. However, previous studies using avian species and dogs have shown that they do not optimise their choice of total overall reinforcement (Laude et al., 2013; Molet et al., 2012; Rachlin, 1990; Zentall & Stagner, 2011a).

To determine the conditions under which animals make sub-optimal choices, early research developed an animal model of gambling using a concurrent-chains schedule with pigeons (Boeving & Randolph, 1975). A concurrent-chains procedure (see, Catania, 1969), requires a subject to choose between two (or multiple) simultaneously available schedules and the subject can switch between each alternative. Reinforcers are produced according to the independent chain schedule. Responding to one initial link schedule (choice phase) disables the other schedule and produces a terminal link (consequence phase) which provides a discriminative stimulus that signals the differential or non-differential schedule of reinforcement that follows (Mazur, 2006). Once the terminal link has been chosen, the other lever becomes dark and inoperative. Each alternative requires the chain of events to be completed in sequence. When the terminal link is completed the reinforcer can be obtained according to the terminal link schedule as shown in Figure 1. A discrete-trials procedure to study choice has been preferred as a single response to one of the initial link options disables the alternative option and the reinforcers are only delivered after a programmed delay. This means that the trial duration and the delivery of the reinforcement can be accurately controlled (Mazur, 1984). Choice responding is controlled during each trial to a single period so that the proportion of choices made for a certain alternative indicates preference during the procedure. There are

different ways to organise the concurrent chains procedure to manipulate the outcomes during the terminal-links such as magnitude (e.g., Zentall & Stagner, 2011a), probability (e.g. Gipson, Alessandri, Miller & Zentall., 2009; Stagner & Zentall, 2010) and delay (e.g. Mattson, Hucks, Grace, & McLean, 2010; Spetch, Belke, Barnet, Dunn, & Pierce, 1990; Zentall & Stagner, 2011b).

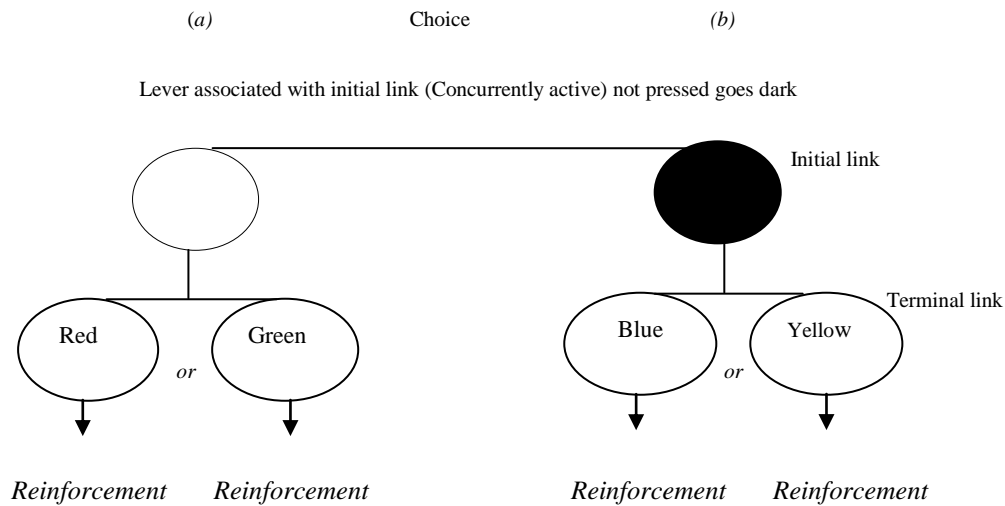


Figure 1. A concurrent chains schedule with multiple terminal link choices.

An initial study on suboptimal choice by Kendall (1974) investigated sub-optimal choice using pigeons. His procedure consisted of a choice of one alternative that provided a white lit key followed by 100% reinforcement. The other alternative led to a choice of green light providing reinforcement 50% of the time or a red light which provided zero reinforcement. Surprisingly, he found that generally the pigeons preferred the sub-optimal alternative that provided 50% of food over the alternative which provided 100% of food.

Fantino, Dunn and Meck (1979) argued that Kendall's (1974) procedure was due to a signalling effect where unlit responses keys were being used during the initial link and was responsible for the sub-optimal preference. Fantino et al. (1979) amended the original study to include illuminated keys during the initial

link; otherwise the procedure remained the same. However, only a small preference for the alternative that provided 100% reinforcement was found. Using a fixed ratio (FR) schedule FR-30 (30 responses per reinforcer) on one alternative and a multiple FR-5, FR-80 (42.5 responses) on the other alternative the pigeons chose to take the sub-optimal choice 100% of the time. Kendall (1985) also replicated his previous experiment using lit keys on the initial link, and still found the pigeons had the same preference for the sub-optimal choice. He did suggest that the preference was only shown when the initial link schedules were short and the terminal link schedules were long (Kendall, 1985).

The earlier research led to an interest in the preference for “information” in the absence of differential reinforcement. For example; it is the value of the information provided by the discriminative stimuli which is more reliable in the presence of the (S+) and the absence of the (S-) of reinforcement, whereas the alternative unreliable stimuli does not provide any “information” (Berlyne, 1957). Traditionally, this was known as the information hypothesis which states that for a stimulus to gain conditioned reinforcement strength, it needs to be informative about approaching reinforcement. For stimuli to be “informative” it must reduce the uncertainty about the reinforcement schedule in effect, and it applies equally to stimuli that signal reinforcement or not (Berlyne, 1957).

Roper and Zentall (1999) examined information theory by manipulating the overall probability of reinforcement. The overall probability was 50% reinforcement and consisted of two alternatives. One alternative signalled reinforcement 50% of the time or a signal for zero reinforcement 50% of the time. The other alternative provided a signal that produced 50% reinforcement on both choices. A strong preference for the alternative that signalled reinforcement or its

absence was found. Roper and Zentall (1999) suggest there was an uncertainty of reinforcement when the initial choice was being made, but the discriminative stimuli provided enough information about the presence (S+) and absence (S-) of reinforcement which significantly reduced the uncertainty of the schedule in effect (Roper & Zentall, 1999).

Also consistent with information theory, Roper and Zentall (1999) found that when the probability of reinforcement was increased for both alternatives to 87.5%, the preference for the sub-optimal (discriminative stimulus) alternative (87.5% or 12.5%) was noticeably reduced. Interestingly, when the overall probability of reinforcement was changed to 12.5% for both alternatives an inconsistency with the information theory emerged. The preference for the sub-optimal alternative increased. According to the theory it should have shown a decrease in preference because the certainty of reinforcement was low (Roper & Zentall, 1999). This indicates that there are other mechanisms involved. Research has shown that rather than information theory, the stronger conditioned reinforcer provides a mechanism that may explain sub-optimal choice (Dinsmoor, 1983; Fantino, 1969; Stagner & Zentall, 2010; Laude, Stagner, & Zentall, 2014).

Dinsmoor (1983) proposed the theory that it is the value of the conditioned reinforcer which could explain the large differences between the results found in the early research (Belke & Spetch, 1994; Dunn & Spetch, 1990; Kendall, 1985; Mazur, 1996; Williams & Dunn, 1991) and the results found in the Roper & Zentall (1999) experiment. Dinsmoor (1983) suggests that a stimulus (S+) that predicts reinforcement with a high probability (e.g., 100%) will become a conditioned reinforcer and will elicit observing behaviour. Results from earlier research did not provide evidence of the influence of the conditioned

reinforcement theory because of the sizable differences found between the animals preference for alternative associated with 50% reinforcement and the preference for the 100% alternative. According to the conditioned reinforcer hypothesis, this would suggest that the pigeons should have been indifferent between the alternatives as both sides were a predictor of reinforcement; however they were not (Zentall, Laude, Stagner, & Smith, 2015).

Using the earlier design, a study examined this hypothesis by making changes to the initial link representing the alternatives with a horizontal and vertical line and varying their location from trial to trial to avoid any side bias. The terminal links included three stimuli; On one alternative one stimulus predicted 100% reinforcement (optimal) and the other alternative (sub-optimal) provided two choice stimuli, one providing 100% reinforcement 50% of the time and the other providing zero reinforcement 50% of the time (see Figure 2) (Smith & Zentall, 2015). The results supported the theory and the pigeons did show indifference between the two alternatives. To ensure that the indifference was not due to the pigeons being unable to discriminate between the initial link stimuli and the consequences, Smith and Zentall (2015) changed the sub-optimal terminal link so that both stimuli were non discriminative (both stimuli predicted reinforcement 50% of the time). The pigeons changed to the optimal alternative now that the sub-optimal alternate was providing unpredictable reinforcement. In addition, to further show the initial stimuli control and the associated consequences, the discriminative function was brought back to the sub-optimal alternative but was changed so the probability of reinforcement of the optimal alternative was 50% (similar procedure used by Roper & Zentall, 1999). Results showed that the pigeons now preferred the discriminative stimuli alternative (Smith & Zentall, 2015).

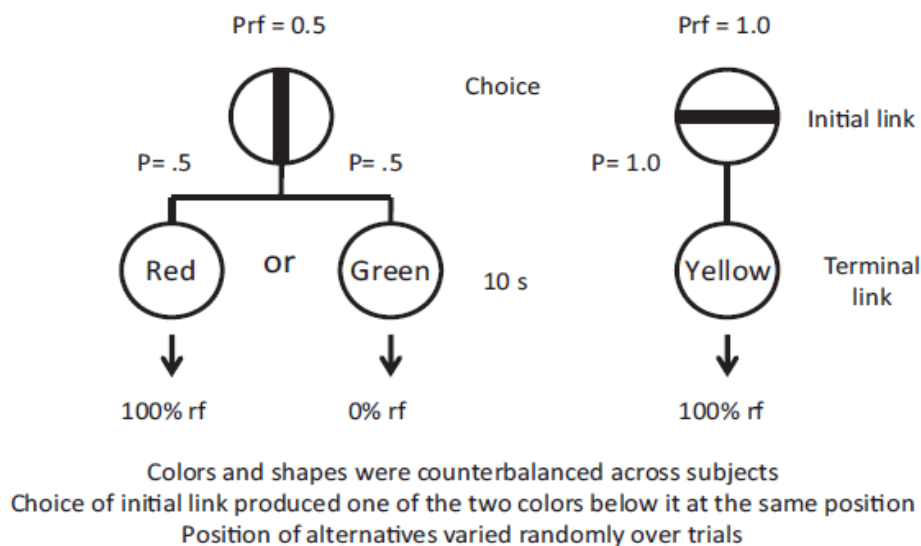


Figure 2. Design of the experiment to test the conditioned reinforcer value hypothesis. Pigeons chose between an alternative that provided discriminative stimuli associated with 50% reinforcement and an alternative that provided a stimulus associated with 100% reinforcement. P = probability of the occurrence of the colour; Prf = probability of reinforcement; rf = reinforcement. Adapted from “Resolving the Paradox of Suboptimal choice” by T. R. Zentall, 2016, *Journal of Experimental Psychological: Animal Learning and Cognition*, 42(1), 1-14. Copyright 2015 by American Psychological Association. Reprinted with permission.

However, the sub-optimal alternative in some experiments also provided an S- that occurred 80% of the time and in some cases four times as often as the stimulus that followed reinforcement (Stagner & Zentall, 2010; Zentall & Stagner, 2011b) which should decrease the value of the conditioned reinforcer (S+). Possibly the S- failed to become a conditioned inhibitor because the pigeons ignored the signal once it was identified as an S- and it maintained little observing behaviour (Dinsmoor, 1985; Gipson et al., 2009). Wasserman, Franklin, and Hearst (1974) presented pigeons with a stimulus that signalled food and the pigeons approached and pecked the stimulus. When they presented a stimulus that signalled an absence of reinforcement, the pigeons refrained from pecking and actively moved away from it. In addition, research has shown that the

effectiveness of a discriminative stimulus is dependent on the duration spent observing that stimulus (Roberts, 1972). Consistent with this hypothesis, pigeons rarely pecked at the S-, whereas they all pecked at the stimuli that was followed by reinforcement (Gipson et al., 2009; Stagner and Zentall, 2010; Zentall and Stagner, 2011a). Interestingly, when the pigeons were able to turn off the S- without affecting the schedule of reinforcement they did (Dinsmoor, 1985). Hence, the S- stimulus would appear to have some inhibitory properties.

Further research examined the possibility that preference for the discriminative stimuli was due to reduced conditioned inhibitory properties that signalled the absence of reinforcement. Pigeons were exposed to an S- with a diffuse house light that could be aversive and difficult to avoid. A control group was included and the light was a signal that reinforcement was available (Stagner, Laude, & Zentall, 2011). The pigeons who were exposed to the diffuse S- continued to prefer the sub-optimal alternative overall, the same as the control group. Hence, the authors concluded that it was not the insufficient experience with the S-; instead the pigeons do not attribute a lot of negative value to the S-. It is notable that it has been found that humans who gamble often attend to the wins (the S+ stimulus) more than their considerably persistent losses (S- stimulus) than occasional gamblers (Blanco, Ibanez, Saiz-Ruiz, Blanco-Jerez, & Nunes, 2000; Breen & Zuckerman, 1999). This finding shows that attention to the conditioned reinforcer is greater than the adverseness of non-reinforcement. This could be significant when developing gambling experiments and to gambling behaviour (see, Breen & Zuckerman, 1999; Blanco et al., 2000, Hayden, Heilbronner, Nair & Platt, 2008).

If the S- plays a minimal role in the sub-optimal preference, this may suggest that the important variable is the outcome-signalling value of the conditioned reinforcer regardless of the frequency it occurs (Zentall & Laude, 2013). Stagner, Laude, & Zentall (2012) examined the conditioned reinforcer hypothesis by manipulating the signalling value of each alternative so that both sides produced conditioned reinforcers. Each of the conditioned reinforcers signalled 100% reinforcement; however one was signalled on 20% of the trials, while the alternative was associated with 50% (see figure 3). As the conditioned reinforcer hypothesis predicts the pigeons should actually be indifferent to the alternatives because the two conditioned reinforcers should have the same value. The results did show indifference for the pigeons. Due to the concern that the pigeon's may have been unable to discriminate between the line stimulus, Stagner et al. (2012) made the optimal alternative non-differential (both 50%) for half the pigeons and for the remaining pigeons both alternatives pairs were non-differential. Pigeons chose optimally for both pairs, whereas the pigeons that had only the non-differential optimal alternative chose sub-optimally. When the groups returned to the original procedure, they were once again indifferent. This provides strong support for the hypothesis that the value of the conditioned reinforcer determines choice (Stagner et al., 2012).

The conditioned reinforcer theory has shown to hold some merit but may not be the only explanation for the findings reported. The theory suggests that the procedure used in earlier research should show that the frequency of the optimal and sub-optimal choices should be equal, but often the results showed the pigeons preferred the sub-optimal choice (Belke & Spetch, 1994; Dunn & Spetch, 1990). In addition, when the choices were reversed the pigeons reversed their preference which does not reflect indifference for the two choices. Furthermore, adding a

delay on the sub-optimal condition reinforcer resulted in a preference for the optimal alternative and varied results were found when the optimal alternative had a 5-s delay. Smith and Zentall (2015) suggest that additional variables may be contributing to the results such as delay reduction theory.

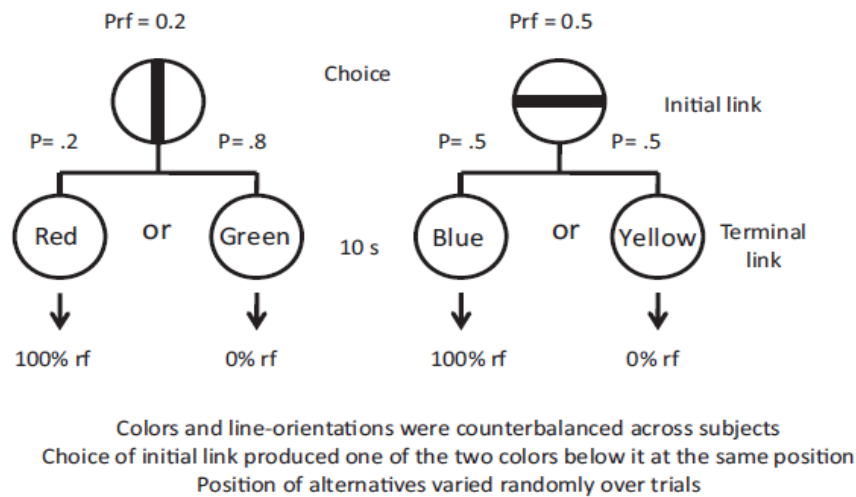


Figure 3. Design of the experiment to test the conditioned reinforcer value hypothesis. Pigeons chose between an alternative that provided discriminative stimuli associated with 20% reinforcement and an alternative that provided discriminative stimuli associated with 50% reinforcement. P = probability of the occurrence of the colour; Prf = probability of reinforcement; rf = reinforcement. Adapted from “Resolving the Paradox of Suboptimal choice” by T. R. Zentall, 2016, *Journal of Experimental Psychological: Animal Learning and Cognition*, 42(1), 1-14. Copyright 2015 by American Psychological Association. Reprinted with permission.

Delay reduction theory (see Fantino, 1969) predicts that the value of the conditioned reinforcer depends on the degree that a stimulus predicts reinforcement in its presence rather than its absence providing that it is associated with a reduction in the delay of reinforcement. As discussed previously, the sub-optimal choice alternative is a strong conditioned reinforcer and the optimal alternative is less predictive so it should not be considered a good conditioned reinforcer. In some experiments the optimal alternative is associated with less than 100% reinforcement (e.g., Stagner & Zentall, 2010) which predicts that the

sub-optimal alternative has a better chance of reinforcement than the reinforcer associated with the optimal alternative. This suggests that delay discounting functions may be beneficial when examining sub-optimal choice. The concept of delay reduction theory assumes that the strength or value of a reinforcer decreases as delay between choice and reinforcer increases and this has been shown by the hyperbolic-decay model (see Mazur, 1997).

Laude, Beckmann, Daniels, and Zentall (2014) tested this hypothesis by manipulating the delay to food using pigeons. Results were consistent with the theory; the findings showed that the pigeons choose the immediate smaller reinforcer over the larger delayed reinforcer. In addition, the steepness of the delay discounting function suggests that choosing sub-optimally was correlated with impulsivity and this could be important to the study of gambling (Laude., et al., 2014; Nower & Blaszczynski, 2006). Interestingly, research has also shown that people addicted to gambling show extreme rates of delay discounting (Nower, Derevensky, & Gupta, 2004; Petry, 2001).

The research suggests that using the sub-optimal task appears to have similarities to the gambling seen in the human environment. Non-human animals, much like humans, choose the alternative that produces low probability and high payoff rather than an alternative that has a high probability but low payoff outcome (Belke & Spetch, 1994; Dunn & Spetch, 1990; Gipson et al., 2009; Stagner et al., 2012; Stagner & Zentall, 2010). Furthermore, the magnitude of reinforcement is even more similar to human gambling and results from a previous study produced the low probability and high payoff alternative (Zentall & Stagner, 2011a). This suggests that the behavioural processes of sub-optimal choice shown by non-human animals produce a good model of human gambling.

This should also suggest that a similar task would show the same behaviours if performed by humans (Molet et al., 2012; Zentall, 2011; Zentall & Stagner, 2011a).

The pigeon task was examined using a version that was modified for humans in the form of a video game (Molet et al., 2012). The subjects were given a sub-optimal alternative that provided a stimulus (a planet with invading space ships) that earned 10 points on 20% of the trials and zero points on the remaining 80% of trials. The optimal alternative exposed them to a stimulus (planet) that earned them 3 points 100% of the time. The authors provided the subjects with a questionnaire prior to the experiment to determine those that frequently gambled and those that did not and divided them into two groups. As shown with the non-human gambling task, the results showed that the gambling group chose sub-optimally significantly more than the non-gamblers (Molet et al., 2012). These results do suggest that the task used with non-human animals could be considered as an analogy of human gambling behaviour, although the results did not determine the variables affecting the sub-optimal choice.

It has been argued that for a model to be more analogous to human gambling, then the alternatives should involve different magnitudes of reinforcement (typically money) rather than different probabilities (Zentall & Stagner, 2011a). Zentall and Stagner (2011a) examined the effect of magnitude using pigeons. The sub-optimal alternative gave 10 pellets of reinforcement on 20% of the trials, average of 2 pellets overall, whereas choosing the optimal alternative produced a definite 3 pellets overall. The preference for the variable 2 pellets over the fixed 3 pellet alternative showed a substantial 86% (Zentall & Stager, 2011a). According to marginal value theorem, when fixed and variable magnitude of

reinforcement are averagely the same, then a preference for the fixed should be shown (see e.g., Rachlin, 1992). Furthermore, the reinforcement for the variable magnitude provided 50% less than the fixed alternative (Zentall & Stagner, 2011a).

To ensure that the pigeons' results were not a product of a preference for the variable over the fixed magnitudes of reinforcement, Zentall & Stagner, (2011a) replicated their experiment. However, the discriminative stimulus was changed to non-discriminative. For example, the choice of 2 pellets per trial (sub-optimal alternative) was changed so that both were equated with 20% chance of providing 10 pellets and on the remaining 80%; both provided zero (Zentall & Stagner, 2011a). Results showed that there was a preference for the optimal alternative (3 pellets overall). Thus, it would appear that the discriminative stimulus is the reason for the preference rather than the variability of reinforcement (Zentall & Stagner, 2011a; Zentall, 2014). The signalling value of the discriminative stimuli was highly valued in Experiment 1. However, in Experiment 2 the value of the discriminative stimuli had weakened as a result of the change to 20% reinforcement making it unreliable as a predictor of reinforcement, thus the pigeons became more sensitive to the other food alternative (Zentall & Stagner, 2011a).

This study is interested in examining whether possums will show the same non-optimal behaviour as pigeons in the studies described above. The first experiment replicated Zentall and Stagner (2011a) and due to the ambiguous results, we decided to partially replicate Stagner & Zentall's (2010) experiment due to the strong preference they found for the sub-optimal alternative. We also examined whether the magnitude used in Experiment 1 was great enough for the

possums to distinguish between the alternatives provided. By making the magnitude on each alternative greater we predicted that the possums will change from being indifferent to choosing an alternative.

Terminology; It should be noted that there is a range of terms and phrases used for the alternatives in the various literature of sub-optimal choice. This thesis will refer to the different meanings as the low probability alternative (sub-optimal) and the high probability alternative (optimal). Depending on the parameters of each experiment, the first mention of each different alternative will be described in parentheses, e.g., (Probability of the occurrence of the line orientations (P) = 20%/80%, Probability of Reinforcement (Prf) = 20%, Reinforcement (Rf) = 100%).

Experiment 1

Introduction

The aim of this experiment is to replicate Zentall and Stagner's (2011) procedure of sub-optimal choice to determine whether possums, like pigeons would make a choice of the alternative that has less overall payoff (sub-optimal) or an alternative that provides an overall greater net payoff (high magnitude of reinforcement). In the first condition, the pigeons showed a preference for the alternative that provided 2 pellets overall (sub-optimal) over an alternative that provided a definite 3 pellets overall (optimal).

To ensure that the pigeons' result in the first condition was not a product of a preference for the variable over the fixed magnitudes of reinforcement, Zentall & Stagner, (2011a) changed the discriminative stimulus to non-discriminative in the second condition. The pigeons showed a preference for the optimal alternative (3 pellets overall). Thus, it would appear that the discriminative stimulus is the reason for the preference rather than the variability of reinforcement (Zentall & Stagner, 2011a; Zentall, 2014).). This Experiment will replicate both conditions from the Zentall & Stagner, (2011a) study. It is predicted that possums will make sub-optimal choices the same as pigeons and change to making optimal choices when we equate the sub-optimal alternative as shown in the previous research.

Method

Subjects

Subjects

The subjects in this study were six brushtail possums (*Trichosurus vulpecula*). Four of the possums were female and two males. At the beginning of this experiment their ages were approximately; Kayla (6 years), Lily (4 years), Joey (3 years), Dusti (6 years), Gus (12 years) and Baxter (11 years). All six possums have had previous experimental experience of pushing a lever to gain reinforcement. Consent for the use of possums in this experiment was obtained by the University of Waikato Animal Ethics Committee (protocol number 925; see **Appendix A** for full ethics application and approval).

The possums were housed individually in cages that had wire walls and floor 540mm wide x 850mm high and 470mm deep, with a nest box 450mm wide x 300mm high sloping from 360mm to 195mm mounted on the top of the cage. Figure 4 shows a photograph of the possum cages. The room where the possums are housed is maintained on a reversed 12 hour day/night light cycle and they were run in the dark phase. The room was illuminated by three 60 watt red lights.

Possums had constant access to water in their cages and their diet was supplemented with pellets (manufactured by Dunstan Manufacturing Ltd), apples or carrot and dock leaves (*Rumex obtusifolius*) were feed after each experimental session. The possums were weighed weekly and their supplementary food was adjusted as necessary to maintain a stable body weight (see **Appendix B**).

Apparatus

Their Individual home cages functioned as the experiments operant chambers. The response panel also functioned as the cage door and was situated at

the front bottom half of the cage. The response panel consisted of two layers; a bronze Perspex (AN-584) inner layer glued to a piece of plywood 550mm high x 320mm wide on the outer side of the cage (refer to Figure 5). A magazine, to deliver food, 195mm x 112mm x 231mm was attached to the centre on the outside of the door. The possums accessed the reinforcement through a hole 30mm x 30mm when the magazine was raised (refer to Figure 5). Reinforcement was a mixture of steamed-flaked barley and Cocoa Pops cereal at a ratio of 15:1 by volume. For all of the possums their reinforcement was changed to extruded maize during experiment two due to the latter no longer functioning as a reinforcer for some of the possums.

Each response panel contained three holes (6mm in diameter) above the magazine to insert response levers. The levers consisted of a micro switch, Honeywell BZ-2RW863/A2. The lever “activator” was reduced in length to extend 15mm through the hole in the panel and was made of thin steel 90mm long, held 80 mm apart by a piece of 160 mm long aluminum bracket, which slotted on screws outside the panel during the experimental sessions and allowed them to be removed when experiments were not in session.

Above the right and left levers two rectangular slots were cut into the panel to hold the LED lights which present the different line orientations during the experiment and above the centre lever a 5mm diameter hole was cut into the panel for an amber LED light (refer to Figure 5). The line orientations on the side or left/right LED stimuli consisted of either a cross (x) or an addition sign (+) which were followed by either a forward/backslash (/ \) or a vertical/horizontal line (- |). The experiment was controlled with Med-PC software, Version IV.



Figure 4. A picture of the possum's individual cages/operant chamber.



Figure 5. A photo of the experimental response panel from the back and the front.

Training

Each session was conducted in the possum's individual cages for 5-7 mornings a week during the possums' night phase. All possums were exposed to training sessions similar to the actual experiment. Most possums received six pre-training sessions except Joey who received 24 sessions and Lily 36 sessions. The session required the possums to make an FR1 response to lever associated with the white centre stimulus and an FR1 response to the side key associated with the line orientations (plus (+) or cross(x)). This led to one of the four line orientations (backslash (\), forward slash (/), horizontal (-) and vertical (l)) and after an FR1 response resulted in access to 3-s of reinforcement; this was followed by a 10-s ITI. There were 84 stimulus presentations per session: six for each of the line orientations on each of the side keys and six of the white stimulus on the centre key. Once the possums responded reliably to this condition they moved onto the first experiment.

Two of the possums required addition sessions on a variable-interval schedule (VI15) due to non-responding once the fixed time (FT) was introduced in the experiment. The session presented 7 stimuli; one white centre light, plus (+), cross(x), backslash (\), forward slash (/), horizontal (-) and vertical (l). Each trial consisted of 3 on the left side, 3 on the right and 1 centre presentation. When the stimulus was presented on either lever a response was required and on a VI15 reinforcement was provided. Lily received 25 sessions and Baxter received 48 sessions before moving on to the first condition.

Experimental Procedure

i. Condition 1

Each session consisted of 60 trials which comprised of 40 randomly alternating forced choice trials which were divided into 20 on the left and 20 on the right lever, with 20 choice trials randomly presented among the forced choice trials. The initial link (x) and (+) alternated between the left and right side. The design of this experiment appears in Figure 6. There were 3 types of trials; Choice, where both alternatives were available simultaneously, Force choice trials, where for half the trials the (x) was presented and on the other half of the trials the (+) was presented. All the trials used the same chained procedure which consisted of a response to the centre lever, initial link presentation (x or + or both), Fixed Time (FT) and consequence. A chained procedure was used to ensure that the same amount of effort required when accessing the discriminative stimuli that reliably predicted the presence of the discriminative stimuli (S+) and the absence (S-) of reinforcement on the low-probability alternative and on the high-probability alternative.

Condition 1 provided two alternatives with probabilities of stimulus presentation being 20% and 80%, respectively. The low probability discriminative stimuli alternative (sub-optimal) reliably signaled a choice of two stimuli, a S+ that provide access to 3.5-s of reinforcement 20% of the trials and a non-discriminative stimuli, an S- that provided zero over the remaining 80%. The high probability alternative (optimal choice), both stimuli provided 1-s reinforcement (100% reinforcement).

The session began with a yellow centre light stimulus and a Fixed Ratio 1 (FR-1) central lever press which resulted in the illumination of one of the side

lever line orientations (plus (+) or cross(x) (initial link). On a forced choice trial, only one of the initial link line orientations (x) or (+) was illuminated line (each of the line orientation could appear equally as often on the left or right). The possums were forced to choose that option.

On the choice trials the possum was presented with both alternatives. An FR-1 response on the (x) or (+) lever resulted in the illumination of the terminal link line orientations. If the (x) was in effect then this produced a backslash (\) or forward slash (/) and if the (+) was in effect than it was either a horizontal (-) or vertical (l).

The terminal link stimuli pairings for both alternatives were presented with a constant probability of 20% and 80%, respectively (4 trials and 16 trials). Once an FR1 response was made the terminal link would remain illuminated for 10-s before the consequence for the stimuli in effect was made available. The low probability alternative (x) signaled a discriminative stimuli (S+); forward slash (/) which reliably predicted access to 3.5-s reinforcement or a stimulus (S-); backslash (\) which provided no reinforcement. The overall probability of reinforcement on the low probability alternative was 20% with an overall reinforcement of 14-s per session.

The high probability alternative (+) signed a non-discriminative stimuli of a horizontal (-) or vertical (l) line. The presentation of either of these two stimuli provided 1-s reinforcement. The overall probability of reinforcement was 100% with the overall reinforcement being 20-s per session.

The 20 choice trials were randomly presented amongst the forced choice trials. During the choice trials both the side line orientations (plus (+) or cross(x)) were illuminated and varied on the left and right sides. The possums were able to

choose either the (+) or (x) lever when the initial link was presented and an FR-1 response presented the terminal link for the chosen stimuli with the same contingencies as in the forced choice trials above.

ii. Condition 2

This condition examined variable over fixed magnitudes independent of the stimuli that signaled them by altering the low probability alternative so both stimuli (/ or \) now provided 3.5-s reinforcement on 20% of the trials. The high probability alternative remained the same. There were 50 forced choice trials which were divided into 25 on the left and 25 on the right lever and 25 choice trials. The change in the number of trials of each stimuli type and number of total trials was necessary to accommodate the change of reinforcement probability associated with the line orientations that signaled 20% reinforcement (from 100% to 20% and 0% to 20%). Thus, this would examine whether the preference in Condition 1 was a product of the different reinforcement or stimulus associations.

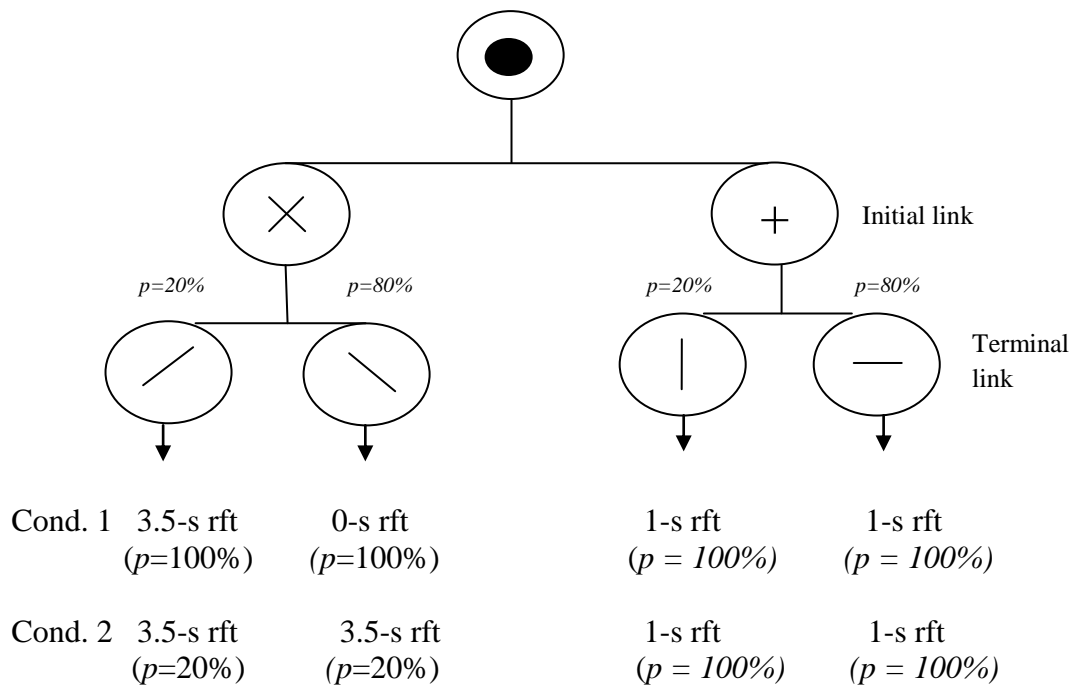


Figure 6. Exp. 1, Condition 1: On choice trials one alternative (x) led to a signal for 3.5-s of reinforcement on 20% or a signal for zero reinforcement on 80% of the trials. The other alternative (+) led to one signal that occurred on 20% of trials or another signal on 80% of the trials, with both signals always providing 1-s reinforcement. Exp. 1, Condition 2: On choice trials one alternative led to either of the two signals for 3.5s of reinforcement on 20% of the time. One signal occurred 20% of the trials and the other on 80%. The other alternative (+) remained the same as Condition 1.

Results

The choice trials examined the number of times each alternative was preferred when the two schedules were concurrently available. The possums completed a different number of sessions in this experimental condition. The final analysis of the data was based on the first 18 sessions and the last 18 sessions for each possum. In Condition 2 the data was based on 36 sessions for Kayla, Joey and Dusti, 26 sessions for Gus, 13 sessions for Baxter and 15 sessions for Lily due to non-responding on earlier training sessions for Baxter and Lily and non-responding during the sessions for Gus. Analyses for these conditions focus on the choice trials data for each session. The complete data set for all the trials are presented in Appendix A.

Data for the low probability alternative ($P=20\%/80\%$, $Prf=20\%$, $Rf=3.5-s$) for all possums were pooled for each session and is presented in Figure 7. The graphs show the percentage for the low probability alternative on the Y-axes and the sessions on the X-axes. The dotted horizontal line through the data shows the point of indifference (50% choice between alternatives), and the solid black circles represents Condition 1, while the white circle points are Condition 2. The choice percentages were calculated by dividing the number of low probability choice responses by the sum of responses made for both alternatives, multiplied by 100.

i. Condition 1

To enable comparison with Zentall and Stagner's (2011) results, the preferences were combined over the last five training sessions for all six possums. The preference for the low probability alternative was 52.6% which shows an indifference between the alternatives and is not statistically significant as determined by a single-sample two-tailed t -test: $t(4) = 1.3679$, $p = 0.2431$, effect size $r = 0.56$. Of the six possums in Condition 1, all possums showed a clear indifference for either alternative over the last five sessions (50%, 51%, 51%, 60%, 53% and 48%).

Figure 8 shows the individual data for each possum over the 36 analysed sessions. Overall, the results show that the possums were consistently indifferent to the choice of reliable stimuli that predicted 20% reinforcement, over the alternative unreliable stimuli that non-differentially provided 100% reinforcement. Kayla, Lily, Joey and Baxter showed some variation, however were on average showing indifference between the two alternatives. Their mean averages were 57%, 61%, 57%, and 56% respectively for the low probability alternative over the high probability alternative. Gus (except for 2 sessions) and Dusti were consistently indifferent throughout the session and both showed a mean average of 50%.

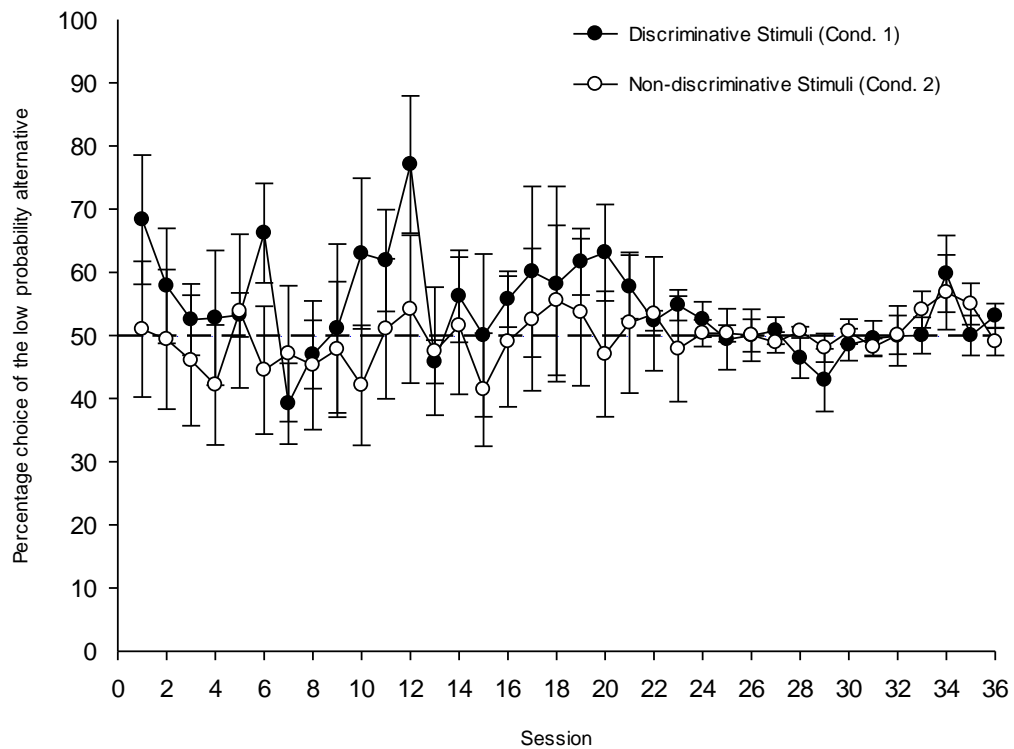


Figure 7. Condition 1 (discriminative stimuli): mean percentage of the preference for the low probability alternative with the discriminative stimuli signalling 3.5-s reinforcement on 20% of the trials and zero on 80% of trials over the preference for constant 1-s reinforcement. Condition 2 (non-discriminative stimuli): mean percentage of the preference for the low probability alternative with the absence of discriminative stimuli; both stimuli signalled 3.5-s on 20% of the trials and zero on 80% of the trials. Error bars represent \pm s.e. of the mean.

Condition 2

Figure 7 shows the overall mean percentage of the low probability alternative ($P=20\%/80\%$, $Prf=20\%$, $Rf=3.5\text{-s}$) for all 36 trials in Condition 2 (white circles). The individual data was also combined over the last five training sessions for all six possums. When the two stimuli were equated on the low probability alternative the (x) initial link lead to the (/) and (\) both providing 20% probability of obtaining 3.5s reinforcement, preference for the low probability alternative was 52.6%. This shows an indifference between the alternatives which is the same as Experiment 1 and is not statistically significant as determined by a single-sample two-tailed t -test: $t(4) = 2.020$, $p = 0.1134$, effect size $r = 0.71$. Of

the six possums in this condition, all possums showed a clear indifference for either alternative over the last five sessions (50%, 55%, 43%, 51%, 57% and 61%).

Figure 8 shows the individual data of the 36 completed sessions for Kayla, Joey and Dusti and 26 for Gus, 15 for Lily and 13 for Baxter. Overall, the results show that the possums were consistently indifferent to the low probability alternative stimuli which unreliably predicted 20% reinforcement, over the alternative stimuli that non-differentially provided 100% reinforcement, which may suggest the signaling value of the stimulus did not predict 3.5-s reinforcement was available. All six possums consistently showed an indifference to either alternative. Kayla showed an overall mean percentage of 50%, Lily completed 15 sessions with an overall mean percentage of 53%, Gus completed 26 sessions with an overall mean percentage of 49%. Baxter completed 13 sessions with an overall mean percentage of 55%. Joey and Dusti showed a mean average of 50% and 47% respectively.

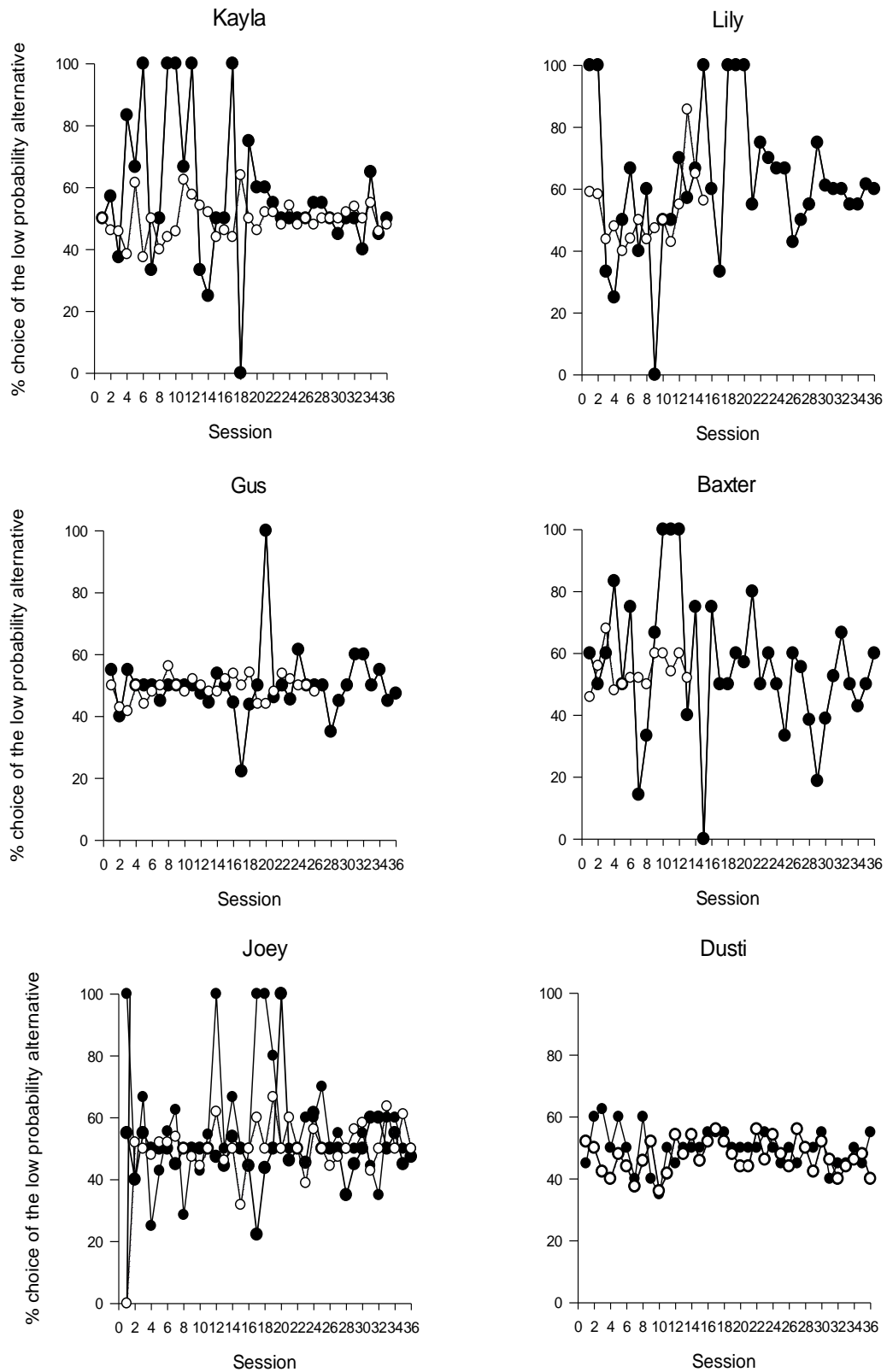


Figure 8. Individual data of each possums with the mean percentage of choice of the low probability alternative (x), with the percentage of each choice trial in black for Condition 1 and white for Condition 2.

Discussion

This experiment aimed to examine sub-optimal choice in possums. It was predicted that the possums would replicate the results of Zentall and Stagner's (2011a) study and show a strong preference for an alternative associated with a low probability but high payoff (sub-optimal) over the alternative that provided a high probability but low payoff (optimal). In addition, to examine whether the low probability alternative depended on the signaling value that predicted the 3.5-s reinforcement.

Zentall and Stagner (2011) found that the pigeons showed a strong preference for the alternative providing discriminative stimuli that signaled the 20% large reinforcement (10 pellets) or the absence of reinforcement 80% of time (see Figure 9). When they pooled the preferences over the last five sessions, the mean score was 82.2% and was significantly different to chance. The results for Condition 2 indicate that when the discriminative stimuli on the low probability alternative were equated, the pigeons showed a preference of 79.9% for the alternative associated with the high probability and low payoff (optimal) over the low probability, higher payoff alternative (sub-optimal).

Overall, in our study the possums did not develop any significant preference for the low probability (sub-optimal) alternative. In spite of our replication across the two conditions, we found that the possums did not replicate the results of the pigeons; however they were robust and consistent. The results showed a clear indifference between the alternatives which suggests that they were insensitive to the consequences and insensitive to the information.

Whilst this finding is unlike that of Zentall and Stagner (2011a), it should be noted that it is very stable and robust across all animals, suggesting a clear effect of the contingencies. It is also possible that it could have been the

alternation of the two alternatives that produced the indifference. A further attempt to examine sub-optimal choice, Experiment 2 will partially replicate Stagner and Zentall's (2010) procedure of sub-optimal choice where the alternative remain constant and examines probability over magnitude to see if this will eliminate the indifference.

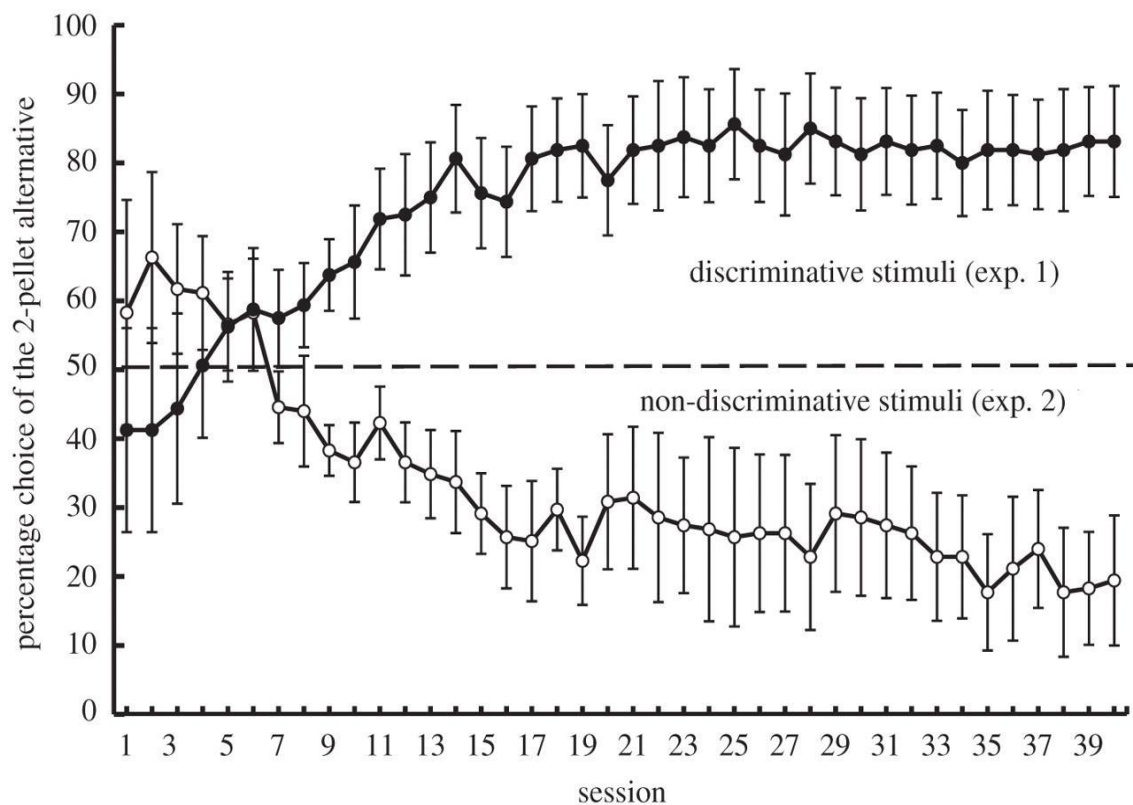


Figure 9. Experiment 1 (discriminative stimuli): acquisition of the preference for a mean of two pellets over a mean of three pellets with discriminative stimuli signalling 10 pellets on 20% of the trials and zero pellets on 80% of the trials over the preference for a constant three pellets. Experiment 2 (non-discriminative stimuli): acquisition of the preference for a mean of three pellets over a mean of two pellets with the absence of discriminative stimuli; both stimuli signalled 10 pellets on 20% of the trials and zero pellets on 80% of the trials. Adapted from “Maladaptive choice behaviour by pigeons: an animal analogue and possible mechanism for gambling (sub-optimal human decision-making behaviour” by T. R. Zentall & J. Stagner 2011, *The Royal Society of Biological Sciences*, 278, 1203-1208.

Experiment 2

Introduction

Due to unambiguous results in our previous study, we decided to partially replicate Stagner & Zentall's (2010) study to attenuate sub-optimal responding with the possums considering their results showed a strong preference for the sub-optimal choice. In this experiment the variable was changed to probability of reinforcement and the alternatives did not alternate. Specifically, a choice between a low probability alternative (sub-optimal) would be on the left lever with discriminative stimuli that reliably predicted an (S+) that provided 20% reinforcement or an (S-) which provided zero reinforcement for the remaining 80% of the trials. The high probability alternative (optimal) would appear on the right lever and provided a non-discriminative stimulus that non-differentially signalled 50% reinforcement regardless of which stimulus was presented. We predict that the possums will prefer the alternative associated with a low probability of reinforcement over the high probability alternative that provides 2.5 times more reinforcement.

Method

Subjects

The subjects used were the same six brushtail possums (*Trichosurus vulpecula*) from the previous experiment.

Apparatus

The apparatus used was the same as the previous experiment.

Experimental Procedure

This experiment is similar to Experiment 1, however the contingencies for the terminal link line orientations were changed from magnitude of reinforcement to probability and the sides remained constant (see Figure 10). The illumination of the terminal link line orientations changed to the backslash (\) providing 100% reinforcement (20% of trials) and the forward slash (/) provided zero reinforcement (80% of trials). The horizontal (-) and vertical (l) line orientations provided 50% reinforcement for both alternatives. Depending on the initial link in effect the reinforcement provided would be a 3-s access to food, or a 3-s blackout.

The design of this experiment is shown in Figure 10. Each session comprised of 120 trials which consisted of 80 randomly alternating forced choice trials which were divided into 40 on the left lever and 40 on the right lever, with 40 choice trials (20 sub-optimal and 20 optimal) randomly presented among the forced choice trials. The procedure for Condition 2 was the same as Condition 1, except the terminal links associated with the (x) and (+) alternatives were reversed. This condition was implemented to ensure that it was the reinforcement contingency rather than a side bias that was responsible for the choice.

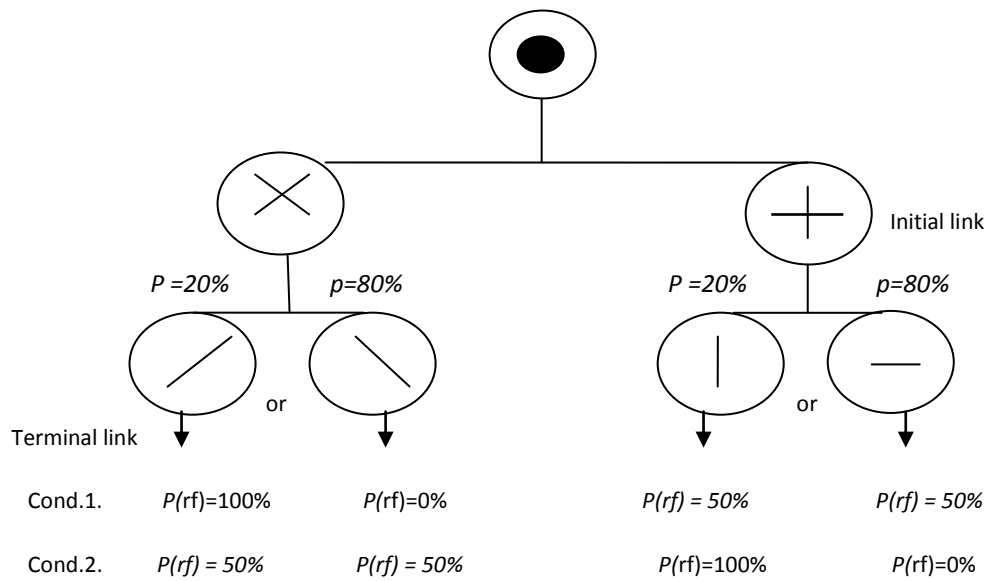


Figure 10. Exp. 2; Condition 1 in which the choice trials provided one alternative associated with 20% reinforcement or absence of reinforcement 80% of the time. The other non-discriminative alternative led to 20% or 80% probability of either choice signaling 50% reinforcement on both. Exp 2; Condition 2 in which the initial link line orientations remain the same as Condition 1 and the terminal link choices have been reversed.

Results

Data for the choice trials for each possum was pooled and both conditions are shown in Figure 12. The graphs show the percentage on the left lever alternative which is associated with the low probability alternative ($P = 20\%/80\%$, $P_{rf} = 20\%$, $R_f = 100\%$) on the Y-axes and the sessions on the X-axes. The experiment began with Condition 1 and then Condition 2, this sequence was repeated so each possum did both conditions twice (Condition 3 and 4). The choice percentages were calculated by dividing the number of low probability choice responses by the sum of responses made for both alternatives and divided by 100. The solid horizontal line shows the point of indifference (50% choice between alternatives).

i. Condition 1

The possums completed a different number of sessions during the experimental conditions. For Condition 1: Kayla 24, Gus 25, Joey 20, Lily 22, Baxter 20 and Dusti 25. For Condition 2: Five possums completed 32 sessions and Baxter completed 27 sessions. Any session that contained no choice responding was also eliminated from the data set. The analysis of the data for both conditions was based on the choice trial data from the first nine sessions and the last nine sessions for each possum. The complete data set for all the sessions are presented in Appendix A.

Results for Condition 1 show that the possums did not acquire a preference for the low-probability alternative associated with 20% reinforcement (see figure 12, Condition 1). The overall group mean for the session was 22% which shows a preference for the high probability alternative (100% reinforcement) over the low

probability alternative (20% reinforcement). On the last (18th) session of the experiment, the mean choice of the alternative associated with 20% reinforcement was 17.7% (SEM = 9.59%) and statistically significant from chance as determined by a single-sample two-tailed *t*-test: [$t(5) = 3.36, p < 0.0200$].

Individual results show that choice for the low-probability alternative (left lever) was initially variable for all subjects and is shown on Figure 13. Kayla and Lily were responding to the low probability alternative on occasion and by Session 7 were exclusively choosing the high probability alternative. Their overall mean percentage was 2% and 10% respectively for the low probability alternative. Gus showed a steady decrease in responding to the low probability alternative and by the 12th session responding remained low for the remainder of the sessions, with an overall mean percentage of 35%. Baxter showed no preference for the low probability alternative and by Session 12 showed no response to that alternative with an overall mean percentage of 4%. Joey showed variability during the sessions and although decreasing on the low probability alternative during session 4 – 6, she remained relatively indifferent. Overall mean percentage of 41%.

ii. Condition 2

The stimuli and reinforcement associated with the initial link (+) and (x) were reversed in this condition, with the left key now being associated with the high probability alternative (unreliable non-discriminative stimuli). The possums switched sides and predominantly showed a strong preference for the high probability preference (($P = 20\%/80\%$, $Prf = 50\%$, $Rf = 50\%$). The overall group mean for the session was 75% which shows a preference for the optimal alternative (100% reinforcement). On the last (18th) session of training, the mean choice of the alternative associated with the high probability alternative was

73.67% (SEM = 12.21%) and is not statistically significant from chance [$t(5) = 1.938, p < 0.1103$].

Individual results showed that Kayla was initially slow to change to the high probability alternative until the 7th session where responding increased. By the 15th session responding to the high probability alternative decreased. Her overall mean percentage was 47%. Lily was responding to the high probability by the 2nd session and was relatively stable with an overall mean percentage of 88%. Gus was responding to the high probability alternative by the 5th session and remained stable with an overall percentage of 81%. Baxter showed responding on the high probability alternative by the 3rd session with an overall mean percentage of 76%. Joey showed 100% responding to the high probability alternative until the 8th session, and then responding decreased to choosing the low probability alternative more frequently. Overall mean percentage of 63%. Dusti was exclusively choosing the high probability alternative by the 6th session with an overall mean percentage of 96%.

iii. Condition 3.

The results show that the possums did not acquire a preference for the low-probability alternative associated with 20% reinforcement (see figure 12, Condition 1). The overall group mean for the session was 27% which shows a preference for the high probability alternative (100% reinforcement). On the last (18th) session of the experiment, the mean choice of the alternative associated with 20% reinforcement was 17.5% (SEM = 16.51%) and is considered not statistically significant from chance [$t(5) = 1.96, p < 0.1061$].

Individual results show less variability than the first session except for Joey. Kayla quickly decreased responding to the low probability alternative and

was exclusively choosing the high probability alternative by Session 4. Overall mean percentage of the low probability alternative was 2%. Lily and Gus reduced their responding to the low probability alternative by Session 3 and were predominantly responding to the high probability alternative during the sessions. Overall mean percentage was 17%, and 26 respectively. Baxter quickly decreased his responding and by the 12th session was exclusively responding on the high probability alternative. Overall mean percentage of 7%. Joey was responding exclusively to the low probability alternative by Session 7. Overall mean percentage was 81%. Dusti decreased responding on the low probability alternative by session 6 and his overall mean percentage was 18%.

iv. Condition 4.

The results for this Condition are similar to the Condition 2. Most possums showed a preference for the high probability (left lever) alternative. The overall group mean for the session was 83% which shows a preference for the high probability alternative (100% reinforcement). On the last (18th) session, the mean choice of the alternative associated with the high probability alternative was 90.33% (SEM = 5.63%) and is considered to be statistically significant from chance [$t(5) = 7.1534, p < 0.0008$].

Individual results showed that most of the possums were responding to the high probability alternative. Kayla was initially slow to change to the high probability alternative until the 10th session and her overall mean percentage was 54%. Lily was responding to the high probability by the 2nd session and was relatively stable with an overall mean percentage of 81%. Gus was slow to change, however responding increased and by the 6th session remained stable on the high probability alternative with an overall mean percentage of 91%. Baxter changed to the high probability alternative by the 2nd session and responding

remained more frequent on that alternative. His overall mean percentage was 80%. Joey was mostly exclusive from the beginning of sessions choosing the high probability alternative with an overall mean percentage of 98%. Dusti was relatively stable on the high probability alternative by the 2nd session and had an overall mean percentage of 96%.

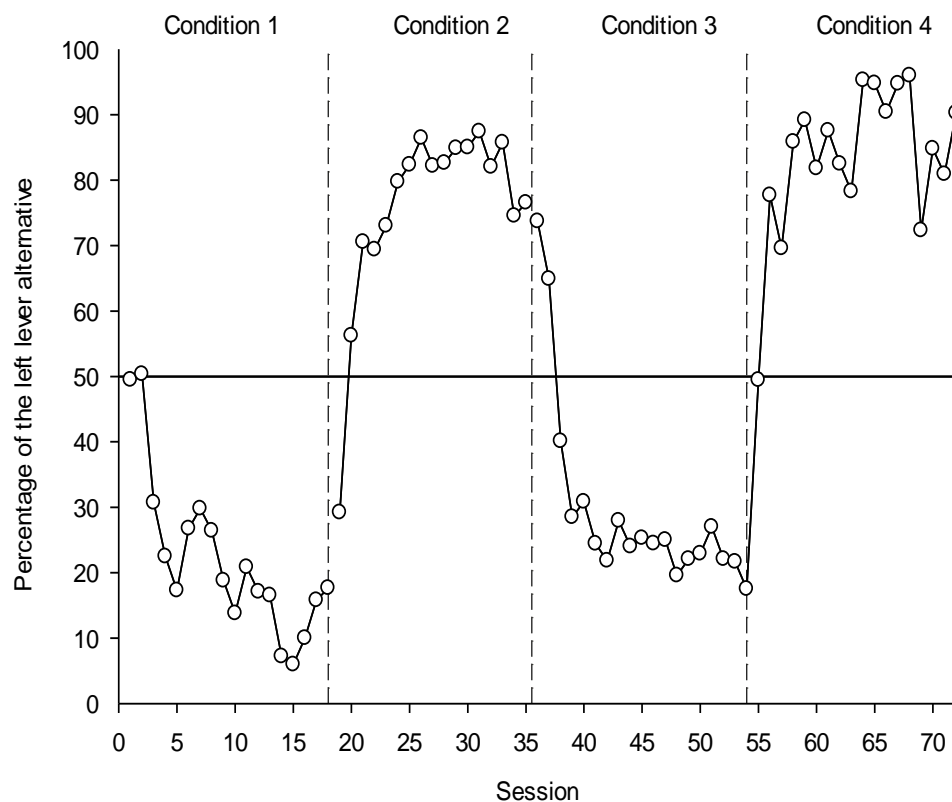


Figure 11. Exp. 2; Condition 1. (discriminative stimuli): Group mean percentage of the preference for the left lever alternative (low probability alternative). Exp. 2; Condition 2: Reversal of the contingencies showing the mean percentage of the preference for the left lever (high probability alternative).

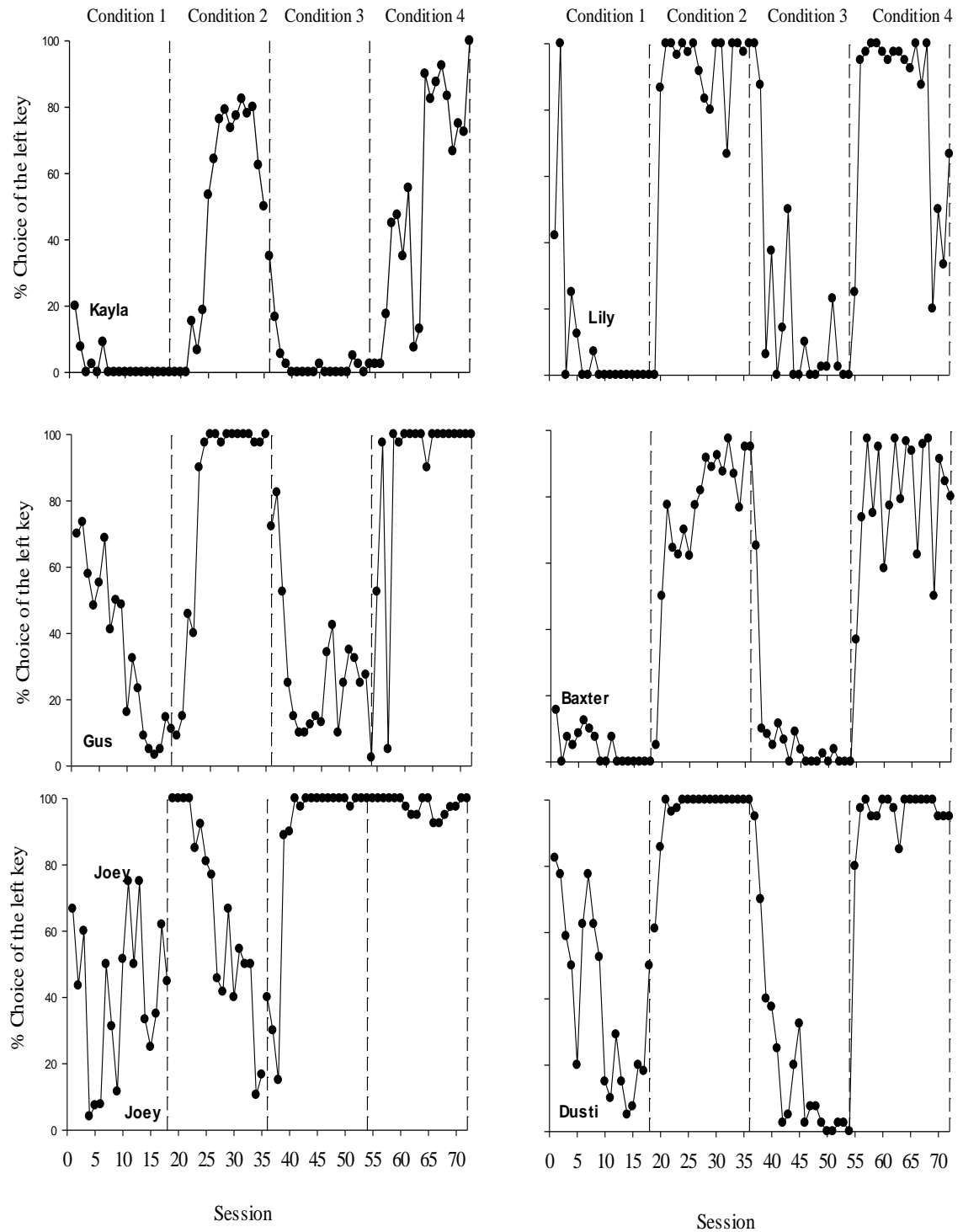


Figure 12. Exp. 2; Condition 1. (discriminative stimuli): Individual data for each possum of the mean percentage of the preference for the left lever alternative (low probability alternative). Exp. 2; Condition 2: Reversal of the contingencies showing the mean percentage of the preference for the left lever (high probability alternative).

Discussion

This experiment aimed to examine the first two conditions from Stagner and Zentall's (2010) experiment. It was hypothesized that the possums would show a strong preference to the alternative associated with a low probability but high payoff (sub-optimal choice) over an alternative that provided a high probability but low payoff (optimal choice).

Stagner and Zentall (2010) found that the pigeons showed a sub-optimal preference for the 20% reinforcement vs. 50% reinforcement which results in a loss of 60% of the food that could have been obtained. The pigeons also reversed their preference when the 20% alternative was shifted to the other side.

Contrary to Stagner and Zentall's (2010) results, overall, the possums did not show a strong preference for the low probability (sub-optimal) choice alternative. Across the four conditions that were replicated we found robust and consistent responding for the high probability alternative (optimal). Interestingly, although we found optimal choice in contrast to Stagner and Zentall (2010), it showed that the absence of alternation appeared to remove the indifferent responding.

Experiment 3

Introduction

The results from Experiment 1 suggest that it may have been the alternation of the alternatives that gave indifference responding. Although Experiment 2 showed that the possums changed to high probability (optimal) responding when the alternatives remained constant, it was not the same procedure as Experiment 1. Considering the differences between experiments it is important that we consider whether we would get a different result without the alternation, using the same procedure as Experiment 1.

Given the findings of Experiment 2, we predict that the alternation accounted for the indifference in Experiment 1. To test this hypothesis we will firstly, replicate Experiment 1, Condition 1 and then examine the same procedure by removing the alternation.

Method

Subjects

The subjects used were the same six brushtail possums (*Trichosurus vulpecula*) from the previous experiment.

Apparatus

The apparatus used was the same as the previous experiment.

Experimental Procedure

All aspects of the experiment remained the same as Experiment 1 for Condition 1. Condition 2 was the same as Experiment 1, except the initial link did not alternate during sessions. The initial link (x) remained on the left side and (+) remained on the right side.

Results

i. Condition 1

The results consist of the choice trial data only. The possums completed 18 sessions on this condition; however any zero responding was removed from the data set. The final analysis of the data was based on the first seven sessions and last seven sessions for each possum. The complete data set for all the sessions are presented in Appendix A.

Figure 14 shows the data for the choice trials which were pooled for each possums and the overall mean percentage for the low probability alternative ($P = 20\%/80\%$, $Prf = 20\%$, $Rf = 3.5-s$) are shown on the Y axes. The preference for the low probability alternative was 51.4% which shows an indifference between the two alternatives and is not statistically different as determined by a single-sample two-tailed t -test: $t(5) = 0.9606$, $p=0.3809$, effect size $r=0.39$.

Figure 15 shows the individual data for the 14 completed sessions. Overall, the results show that the possums were consistently indifferent to the choice of the reliable stimuli that predicts 20% reinforcement, over the unreliable stimuli that non-differentially provided 100% reinforcement. Kayla, Lily, Gus, Baxter, Joey and Dusti showed a clear indifference for either alternative and their overall mean percentage was 46%, 57%, 50%, 50%, 54% and 51% respectively.

Condition 2

The results for this condition were also pooled for all possums over 19 sessions. Figure 14 shows the overall mean percentage of the low probability alternative. The possums did not show a preference for the low probability alternative. Most of the possums preferred the high probability but low payoff

alternative (optimal) and it is not statistically significant as determined by a single-sample two-tailed t -test: $t(5) = 1.6646$, $p = 0.1569$, effect size $r = 0.59$.

Figure 15 shows the individual data from the 19 sessions. Kayla, Lily, Gus, and Baxter did not show a preference for the low probability alternative showing an overall mean percentage of 1%, 5%, 7% and 1% respectively. Dusti showed a preference for the low probability alternative from Session 1 to 11 until decreasing and changing to the high probability alternative (optimal). However, Joey was the exception during this condition where he was stable and exclusively choosing the low probability alternative by Session 2 with an overall percentage of 94%

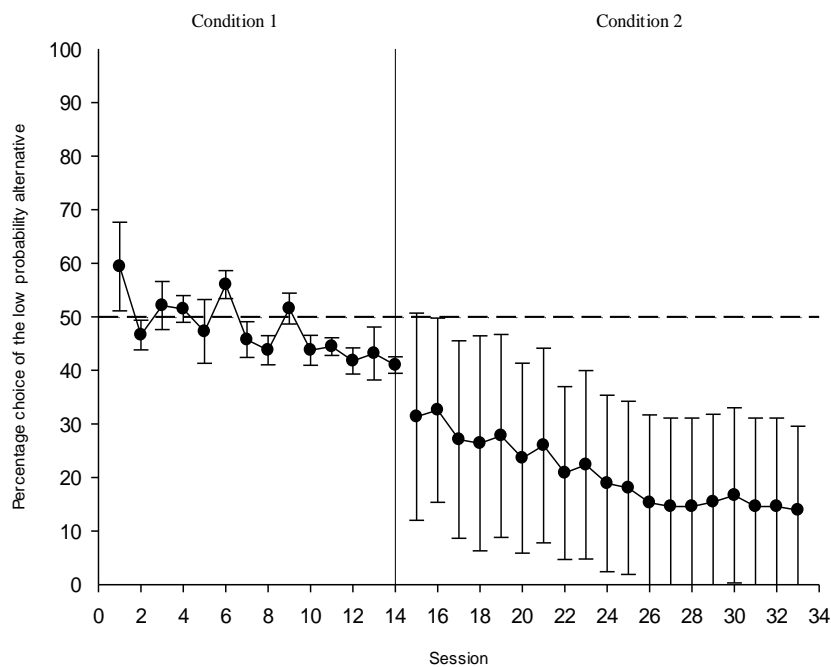


Figure 13. Condition 1 (discriminative stimuli): Group mean percentage of the preference for the low probability alternative with the discriminative stimuli signalling 3.5-s or zero reinforcement over the preference for 1-s reinforcement. Condition 2 (non-discriminative stimuli): mean percentage of the preference for the low probability alternative with the absence of discriminative stimuli; both stimuli signalled 3.5-s on 20% of the trials and zero pellets on 80% of the trial

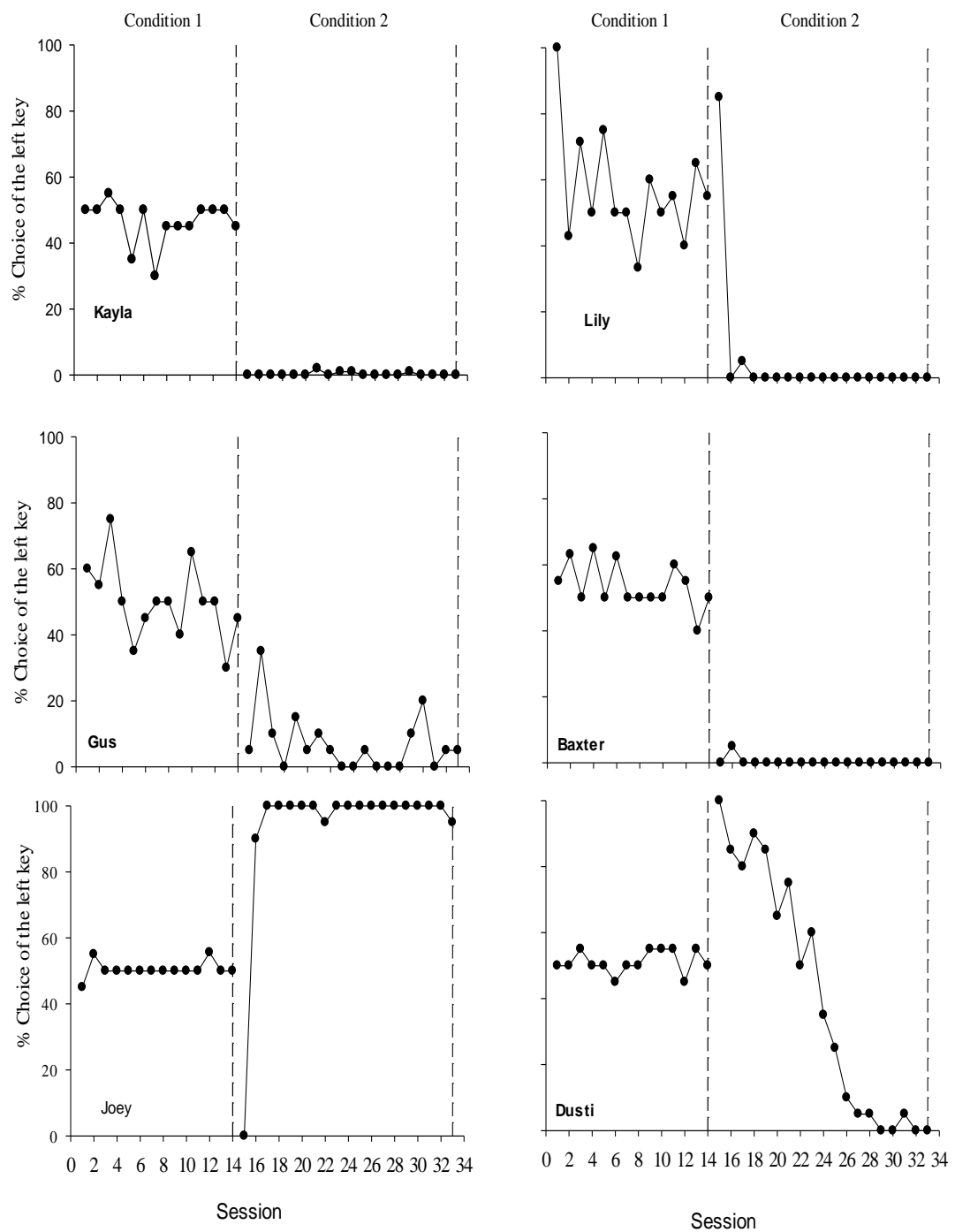


Figure 14.. Individual data for each possum with the mean percentage of choice of the low probability alternative (left key) for each session across both conditions.

Discussion

The finding for this Experiment replicated the findings of Experiment 1; Condition 1 and the possums showed indifference for either alternative. For Condition 2, the alternation was removed and the results were showing a preference for the high probability alternative (optimal) except for Joey who did show a preference for the low-probability alternative (sub-optimal), as was suggested by the findings in Experiment 2.

This leads to the conclusion that it is the alternation that is responsible for the indifference in responding seen in possums. Whilst this has demonstrated the role of alternation with indifferent responding, the question remains as to why the responding is optimal contrary to the findings of Stagner and Zentall (2010).

Experiment 4

Introduction

This experiment is a replication of Experiment 1 but designed to account for the variable of optimal responding seen in Experiment 2. Condition 1 & 2 of Experiment 1 was replicated for comparison purposes, without the alternation to eliminate indifferent responding. The purpose of exaggerating the magnitude of reinforcement is to be more consistent with Zentall & Stagner (2011a) and may help to recover the sub-optimal choice. This experiment will examine the magnitude of reinforcement to investigate whether this would show a similar bias toward the sub-optimal alternative in the way that information biases animals towards responding sub-optimally.

Method

Subjects

The subjects used were the same six brushtail possums (*Trichosurus vulpecula*) from the previous experiment.

Apparatus

The apparatus used was the same as the previous experiment.

Experimental Procedure

i. Condition 1

All aspects of the experiment remained the same as Experiment 3; Condition 2 except reinforcement was changed to a larger magnitude. (see Figure 13). The low probability alternative (x) signaled a discriminative stimuli (S+); forward slash (/) was changed from 3.5-s to 6-s and the backslash (\) remained the same. The overall probability of reinforcement on the left lever (sub-optimal) was 20% with a total reinforcement of 24-s per session.

The high probability alternative (optimal) provided presentation of a horizontal (-) or vertical (I) line. Both stimuli that predicted 1-s reinforcement were changed to providing 1.5-s. The overall probability of reinforcement on the right lever was 100% with the overall reinforcement being 30-s per session.

ii. Condition 4.

This experiment was the same as Condition 1 above except the discriminative stimulus was equated to make it a non-discriminative stimulus. Both the (/) and (\) both provided 6-s reinforcement 20% of the time. (Refer to Figure 13).

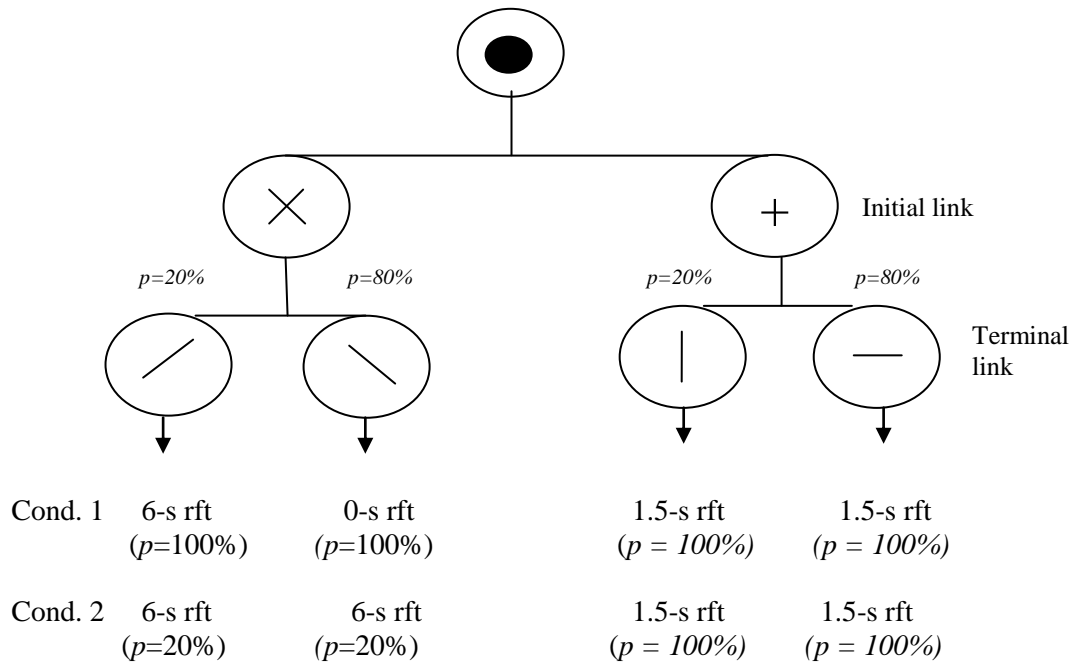


Figure 15. Condition 1: On choice trials one alternative led to a signal for 6-s of reinforcement on 20% or a signal for zero reinforcement on 80% of the trials. The other alternative led to one signal that occurred on 20% or another signal on 80% of the trials; however both signals always led to 1.5-s reinforcement. Condition 2: On choice trials one alternative led to either of the two signals for 6-s of reinforcement on 20% of the time. One signal occurred 20% of the trials and the other on 80%. The other alternative remained the same as experiment 1.

Results

i. Condition 1

Five possums completed 15 sessions of this condition; however, due to Baxter not responding in the earlier training session he only did 12 sessions. Any zero responding was removed from the data set. The final analysis of the data was based on the first six trials and last six trials for each possum. Figure 14 shows pooled data for all six possums with overall mean percentage of the low probability alternative. Preference for the low probability alternative provides a greater magnitude of 6-s reinforcement. The results showed an overall mean percentage for all six possums of 19.5%. This shows a greater preference for the high probability but low payoff alternative (optimal) and is considered very statistically significant as determined by a single-sample two-tailed t -test: $t(5) = 4.9588$, $p = 0.0043$, effect size $r = 0.91$.

Individual data shows that all possums except Gus and Joey started the sessions with a preference for the low probability alternative ($P = 20\%/80\%$, $Prf = 20\%$, $Rf = 6$ -s). Refer to Figure 15. Kayla preferred the low probability alternative until the 6th session, where she rapidly decreased to responding on the high probability alternative and showed an overall mean percentage of 38%. Lily preferred the low probability alternative and by Session 4 had changed to responding on the high probability alternative. Gus was not responding to the low probability alternative from the beginning of the sessions and had an overall mean of 16%. Baxter did not show preference for the low probability alternative and by the 3rd Session was exclusively responding to the high probability alternative with an overall mean of 19%. Joey showed no preference to the low probability alternative and showed an overall mean of 1%. Dusti showed an initial preference

to the low probability alternative with a decrease by the 4th session and an increase on the 7th and 8th session until by the 9th session there was little or no responding to the low probability alternative. His overall mean was 37%.

ii. Condition 2

Five of the possums completed 19 Sessions, however, Baxter only completed seven sessions and any zero responding was removed from the data set. The final analysis of the data was based on the first nine sessions and last nine sessions for each possum except for Baxter. Figure 14 shows the overall mean percentage for all possums. The preference for the low probability alternative was equated at 20% reinforcement for obtaining 6-s reinforcement. The overall mean percentage for all six possums was 52%. This shows a clear indifference to either the low or high probability alternative and it is not statistically significant as determined by a single-sample two-tailed t -test: $t(5) = 1.3574$, $p = 0.2327$, effect size $r = 0.52$.

Individual results are shown in Figure 15. During all the sessions the possums showed an indifference to the low probability alternative and high probability alternative. The results showed clear indifference with overall mean percentage showing Kayla 51%, Lily 60%, Gus 51%, Baxter 49%, Joey 50%, and Dusti 52%.

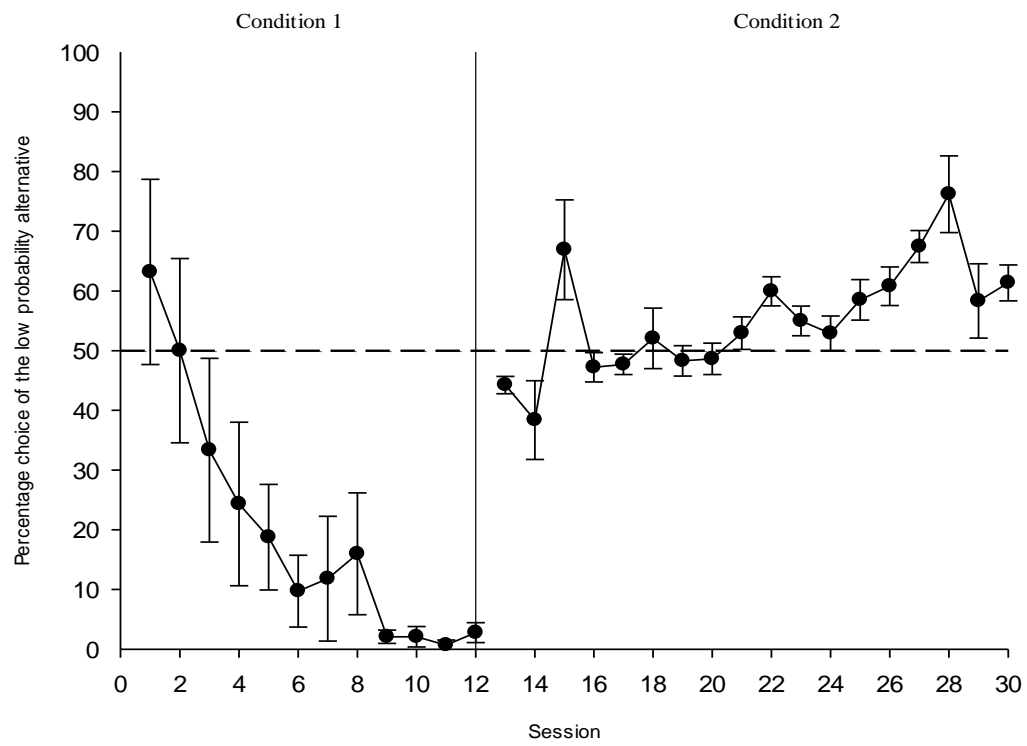


Figure 16.. Condition 1: Group mean percentage of the preference for the low probability alternative signalling 6-s or zero reinforcement. Condition 2: mean percentage for the discriminative stimuli where both stimuli provide 6-s on 20% of trials and zero reinforcement on 80% of the trials. Error bars represent \pm s.e. of the mean.

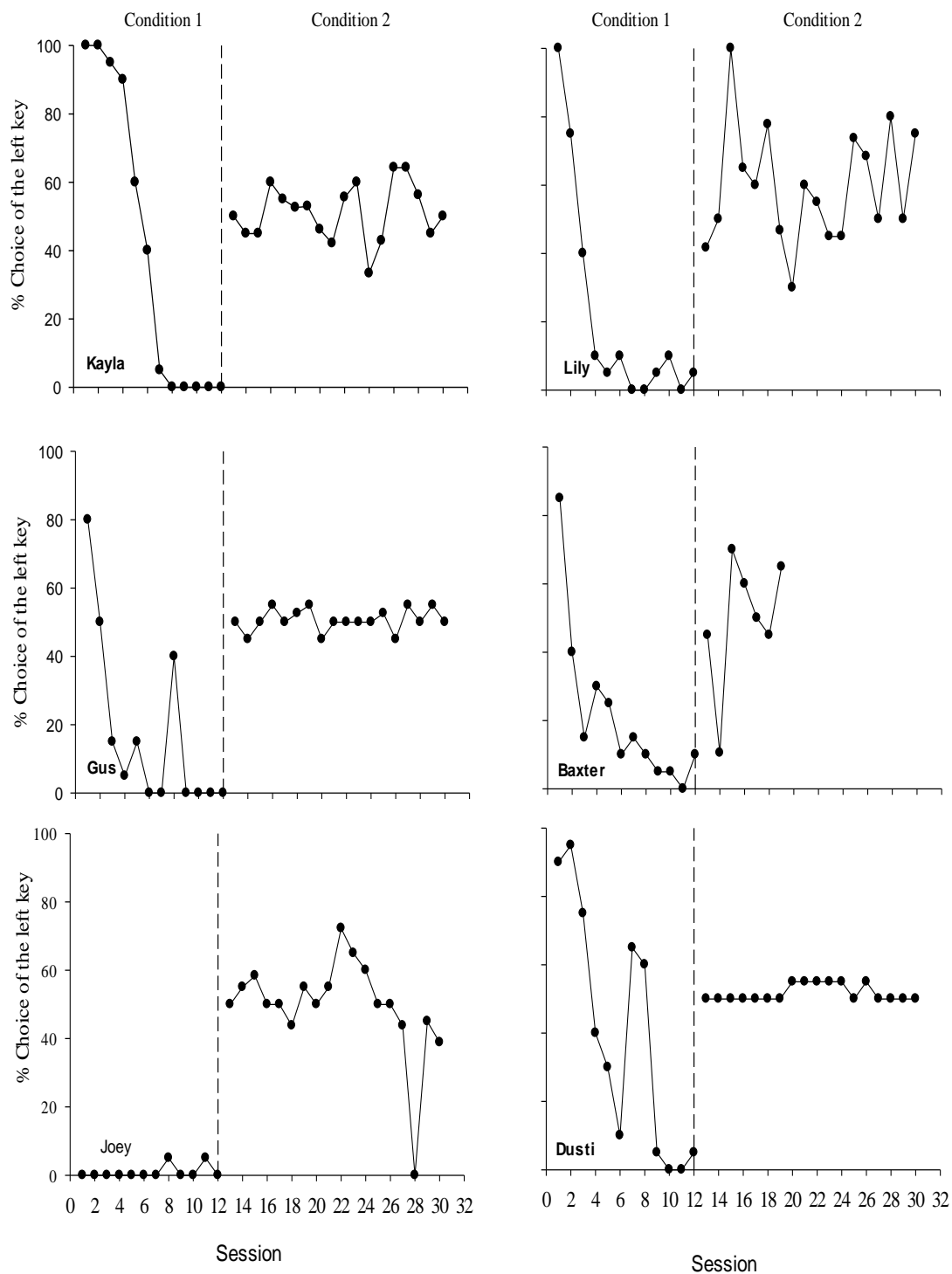


Figure 17. Individual data for each possums showing the mean percentage of choice for the low probability alternative (left key) for each session across both conditions.

Discussion

By providing a larger magnitude of reinforcement on Condition 3, it was expected that the possums may change to the low probability alternative. However, they again showed a preference for the high probability (optimal) alternative and when the discriminative stimuli alternative was equated; they showed a clear indifference for either choice.

Even though the size of the reinforcement on the low probability alternative had doubled, the possums still preferred the high probability of reinforcement in Condition 1. This result suggests that it is not magnitude of reinforcement but the rate of reinforcement irrespective of the information provided on the alternatives.

When the alternatives were equated to make them both non-discriminative stimuli, we found the same effect from Experiment 1, Condition 2. The results showed a clear indifference between the alternatives which suggests that they were insensitive to the consequences and insensitive to the information.

General Discussion

This experiment was to evaluate whether possums would make sub-optimal choices as has been demonstrated by pigeons in previous research. The aim was to determine whether possums would show a preference for discriminative stimuli that reliably predicted less reinforcement (sub-optimal) over stimuli that unreliably predicted more reinforcement (optimal).

In contrast to the consistent preference of the pigeons for the sub-optimal alternative seen in Zentall and Stagner's (2011a) experiment, we found that possums were indifferent to either alternative. When the value of reinforcement on the terminal links were increased, the possums were either indifferent or had a preference for the non-discriminative (optimal) alternative. Even when the discriminative alternative was changed to non-discriminative (equated), the possums showed indifference between the discriminative and non-discriminative alternatives.

This leads to the question as to why do pigeons and possums show different behaviour in the same task. It could be possible that the results show a real inter-species difference between pigeons' and possums' behaviour in the sub-optimal procedure. However, while this is a possibility, there is no obvious reason here to explain why these species should produce such different results

Another possible reason for the difference is that the possums were unable to discriminate between the alternatives. Our experiments used the same line orientation stimuli; (x) or (+) and the discriminative alternative (/) or non-discriminative alternatives (-|). The indifference in responding may be due to the possums being unable to discriminate between the initial link (x) and (+) and/or the terminal link stimuli. If the possums could not discriminate between the two

stimuli then they would be unable to differentiate between the optimal and sub-optimal alternatives and so must behave indifferently. It is improbable that this difference in the procedure was due to the possums being unable to discriminate because past research using possums showed they reliably discriminated between horizontal and vertical line orientations in a conditional discrimination procedure (Hardaker, 2006).

Another possibility could be that the difference in the magnitude of reinforcement between the two alternatives may have been too small for the possums to discriminate. However, in Experiment 3 the magnitude of reinforcement was the same as Experiment 1, except the two alternatives remained constant instead of switching sides. Yet, under these conditions, the possums were reliably choosing one alternative thus; they were able to discriminate the magnitude between the two alternatives.

If the possums can discriminate between the stimuli and the magnitude of reinforcement, then the indifference in responding seen in Experiment 1, may be due to the randomly alternating sides for the two alternatives. It seems that rapid alternating prevents the alternatives from being discriminated. When Experiment 3 was the same, except the alternatives remained on the same sides the possums were able to reliably choose one alternative. This strongly suggests that it is the alternation of the alternatives that led to the indifference as this was the only change made to the experiment between Experiment 1, Experiment 3, Condition 1 and Experiment 3, Condition 2.

There is a notion that alternation of the alternatives disrupts discrimination. Foraging research understands behaviour as responses emitted to acquire a richer resource and also to gain information about achieving that resource. (Dow & Lea,

1987; Stephens & Kerbs, (1986). In a frequently changing environment when the information about the contingencies for reinforcement are inadequate, such as the alternating of the two alternatives, then it is difficult to determine enough information not only for the reinforcement contingencies but also any other response-contingencies, therefore behaviour will be allocated to both tasks, i.e. indifferent responding (see, Dow & Lea, 1987). The possums were able to determine a choice for the optimal alternative when they were exposed to an unchanging environment and therefore learn where to allocate their behaviour to acquire the richer resource. This also suggests that it is the alternating that creates the difficulties.

Stagner and Zentall (2010) accounts for the sub-optimal choice in pigeons due to the conditioned reinforcement associated with the S+ and conditioned inhibition associated with the S-. Our results show that the possums had a preference for the optimal alternative, which suggests that the possums were not motivated by the conditioned reinforcement, but may be more sensitive to the overall probability of reinforcement for both alternatives. In Experiment 2, our findings showed that it was the optimal choice that reliably predicted reinforcement and did not show that the possums associated the S+ and S- with the same value as pigeons. In addition, the equating phase in Experiment 1 (cond. 2) and Experiment 4 (cond. 2), the possums showed a clear indifference between the alternatives which suggests that the signalling value of the conditioned reinforcer (low-probability stimuli) did not control their behaviour, but instead the reinforcement rate did.

Interestingly, possums are not the only species that have found optimal responding when using a similar procedure to the pigeon studies. A study on rats

showed that they had a strong preference for the optimal alternative in contrast to pigeons (Trujano & Orduna, 2015). The rats showed the same indifferences and optimal responding as those reported in our study because both the rats and possums seemed to more sensitive to the overall probability of reinforcement, whereas the pigeons were influenced by the signalling value of the conditioned reinforcement.

It may be possible, that as Mazur, (2007) suggested, more pavlovian contingencies related to the pigeons' 'key-pecking' than in rats' 'lever pressing' which is similar to possums' lever pressing, could partially explain the differences between them. Future research on other types of operant responses with difference species would be required to evaluate whether this has any relevance on sub-optimal choice.

Sub-optimal choice behaviour has scientific and social relevance when considering problem gambling behaviour, if it is analogous to gambling. However, our results show there is a clear difference between pigeon's sub-optimal behaviour and possum's optimal behaviour. Further research on sub-optimal choice using other species and responses would be a benefit to get a better understanding of the degree of generalisation across species and the variables that control the behaviour between species.

Appendix A

Excel files with a summary of raw data are attached on the accompanying CD.

Appendix B

Possums weights during experimentation are attached on the accompanying CD.

Appendix C

Ethics approval (protocol number: 925), is attached on the accompanying CD.

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