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**Suboptimal Choice Behaviour across Different Reinforcement
Probabilities**

A thesis

submitted in fulfilment

of the requirements for the degree

of

Masters of Applied Psychology in Behaviour Analysis

at

The University of Waikato

by

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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

2015

Abstract

Six adult roosters' choice behaviour was investigated across a series of five experimental conditions and a series of replication of the same five experimental conditions. Stagner and Zentall (2010) found that pigeons prefer to choose an alternative with highly reliable discriminative stimuli but with less food reward over an alternative with non-discriminative stimuli but with more food reward. The current research systematically changed the probability of reinforcement associated with the discriminative stimulus through a series of experimental conditions. Experimental sessions were completed with six adult roosters. The experimental procedure was based on Stagner and Zentall's (2010) experiment in which the suboptimal alternative with discriminative stimuli was associated with 100% reinforcement on 20% of the trials, and non-reinforcement on 80% of the trials; the optimal alternative with non-discriminative stimuli was associated with both 50% reinforcement on all trials. This research modified the probabilities of reinforcement associated with the discriminative alternative. In the first experimental condition, the probability of getting access to reinforcement was the same (50%) for each discriminative stimulus, thus, what was seen for the first time was that both alternatives were associated with non-discriminative stimuli. To insure reliability, a replication of the conditions was done after the first five experimental conditions were completed. The results showed that four of the roosters had suboptimal choice behaviour in the first five experimental conditions; however, only two of them maintained such suboptimal behaviour in the replication conditions. This result does not support the idea that the suboptimal choice behaviour with strong discriminative stimuli is a robust effect.

Acknowledgements

I would like to thank Dr. James S. McEwan and Professor Lewis A. Bizo for all your guidance, support and assistance for helping me to complete this thesis through this whole academic year. I would also like to acknowledge technician, Jennifer Chandler, research technician, Rob Bakker and systems administrator, Allan Eaddy for providing assistance for designing, setting up experiments and relative programs and for providing continuous support throughout the undertaking of this thesis. I would especially like to thank Surrey M, K. Jackson and Sheeba Devan-Rolls for proofreading my thesis. Finally, I would like to thank all the staff and students of the animal laboratory for running my experiments, maintaining experimental equipment, and caring for the roosters.

Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
List of Tables	v
List of Figures.....	vi
Introduction.....	1
Human Gambling Behaviour	1
Pathological Gambling and Addiction.....	2
Prevalence and Harmfulness.....	3
Challenges to Human Research	5
Animal Suboptimal Choice Behaviour	6
Animal Analogue of Gambling Behaviour in Current Research	11
Methods	14
Subjects.....	14
Apparatus	14
Procedure	15
Training Phases.....	15
Trial Procedure.....	17
Experiment Procedure.....	18
Experiment Conditions	20
Conditions 1-5.....	20
Replication Procedure	22
Results.....	23
Results of the Conditions One - Five.....	24
Results of Replication Conditions.....	27
References.....	32

List of Tables

Table 1. <i>Order of experimental Condition 1 ~5: the probability of presenting different colours and the times of reinforcement corresponding to each stimulus.</i>	20
Table 2. <i>The number of sessions completed within each experimental condition.</i>	24

List of Figures

<i>Figure 1.</i> Gipson's (2009) experimental procedure. Both sides' alternatives show to each pigeon.	10
<i>Figure 2.</i> General procedure of CRF phase.	16
<i>Figure 3.</i> General procedure of FI 10-s phase.	17
<i>Figure 4.</i> Diagram of the procedure of the experimental and reinforcement (Rft) magnitude associated with each colour stimulus.	21
<i>Figure 5.</i> Raw experimental data.	26

Introduction

Human Gambling Behaviour

According to archaeological data, gambling has a long history which can be traced back to two thousand years ago (Livingston, 2008; Lyons, 2006). Gambling can be defined as a behaviour that is intended to win money or other desirable resources (*Gambling Act 2003*, 2010; Lyons, 2006). It is normally considered a behaviour that only people do. Human gamblers generally have two common characteristics: the first one is that the gamblers believe that the money they win is larger than the wager they pay; and the second is that experiencing very few winnings does not reduce their gambling behaviour (Zentall & Stagner, 2011a). In spite of the perception that gamblers' costs always outweigh the benefits, gambling behaviour still persists (Binde, 2005; H. Breen, 2008).

Gamblers often have the illusion that they have the capability to control the outcomes of winning and losing (Beach & Lipshitz, 1996; Clark, Lawrence, Astley-Jones, & Gray, 2009). People who tend to gamble always undervalue the losses and overvalue the winnings. In other words, human gambling behaviour is a kind of suboptimal choice behaviour in which choosing the option that is not in a person's best long term interest often occurs, for example, buying lottery tickets or playing a slot machine at a casino (Laude, Stagner, & Zentall, 2014).

Researchers suggest that this illusion could result from the availability heuristic that winning can finally cover losses and result in more gains (R. B. Breen & Zuckerman, 1999; Tversky & Kahneman, 1974). However, researchers do not fully understand the explanatory mechanisms of human gambling

behaviour. That is, what factors cause gamblers to gamble is still unclear (Lyons, 2006).

Pathological Gambling and Addiction

Once gambling behaviour becomes pathological, gambling behaviour can be harmful to humans. In other words, when gambling behaviour starts to harm the gamblers, it is said that these people are suffering from problem gambling or pathological gambling (Dickerson, Mcmillen, Hallebone, Volberg, & Woolley, 1997). Pathological gambling is defined as a mental health issue which is associated with losing the ability to control individuals' impulses (Adriani, Zoratto, & Laviola, 2012). When people start to gamble pathologically, they are often seen to be thrill seeking and risk taking (Adriani et al., 2012).

Addiction behaviour is a kind of harmful behaviour of humans, which is hard to manage, occurs over long term and is characterized by repetitive behaviours (Lyons, 2006). The main characteristic of the concept of addictive behaviour is that the organism loses the ability to cease the established addictive behaviour and is associated with a high probability of relapsing to the addictive behaviour when the organism is trying to quit (Lyons, 2006). Gambling behaviour is the only non-substance addiction which has been recognized in DSM-V. This shows how serious gambling problems are to humans and that researchers should put more efforts in to understanding it.

When talking about pathological gambling from a psychological view, gambling behaviour generally occurs for two reasons. The first one is that

gambling is a common example of “risk decision-making” (Clark et al., 2013), the second one is that currently pathological gambling behaviour is described as behaviour addiction and further study in pathological gambling behaviour can provide clues for discovering addictive mechanisms without exposures to substances (Clark et al., 2013). Neuropsychological and physiological studies show that dopamine plays an important role in decision making for both human beings and non-human animals (Adriani et al., 2012; Anselme, 2013; Johnson, Madden, Brewer, Pinkston, & Fowler, 2011).

Anselme (2013) demonstrated that animals tend to show a preference for an option with unpredictable rewards over an option with certain more rewards. These findings are contrary to both optimal foraging theory and the reinforcement mechanisms (Anselme, 2013). Both the optimal foraging theory and the reinforcement mechanisms suggested that animals should always attempt to enlarge the reward they would get from the environment over the short term (Anselme, 2013; Bateson & Kacelnik, 1997). When animals prefer to choose an option with unpredictable rewards over an option with certain reward, their choice behaviour is similar to human gambling behaviour. In addictive gamblers, losing occurs more often than winning, thus, for gamblers, the rewards are less reliable and less frequent (Anselme, 2013; Clark et al., 2013; Clark et al., 2009; Lyons, 2006; Tse et al., 2012).

Prevalence and Harmfulness

Lyons (2006) reported that gambling behaviour is widely popular across different classes, cultures, and races. Gambling behaviour has become global.

Surveys in many countries have indicated that more people gamble than not (Lyons, 2006). Demographic statistics show that more than 67% adults in United States participate in gambling daily, and that only less than 10% of Australian and British adults have had no experience of gambling activities (Lyons, 2006). In the last three decades, legalized gambling activities have been increasing in the United States, Australia, Britain and other nations around the world. This is because governments found that public gaming (e.g. buying lottery tickets or playing slot machines at casinos) could provide financial resources through the tax system (Lyons, 2006). This kind of implicit support from the government perhaps fostered common acceptance of gambling behaviour, and result in more and more people reporting that they cannot manage their gambling (Lyons, 2006).

However, increases in gambling activities lead to people losing money. Thus, gamblers become poorer and poorer which will trigger extensive and serious social problems. The expansion of legalized gambling activities makes more people who work with gamblers worry about the millions of people who are becoming compulsive gamblers (Lyons, 2006). These people who are suffering from pathological gambling have a high chance of suffering from financial ruin, unemployment, divorce (Lyons, 2006), mental health problems, substance abuse, and suicide (Raylu & Oei, 2002).

Human gambling behaviour is generally affected by social, cultural, environmental issues, and individuals' attitudes (Tse et al., 2012). More than 83% of New Zealanders have had the experience of participating in gambling and the percentage of occasional gamblers becoming pathological gamblers is increasing (Abbott, 2001). New Zealand is a multicultural country, therefore, whenever

considering gambling research in a New Zealand context cultural differences should be considered carefully (Tse et al., 2012). However, it is clear that it is necessary and urgent to develop therapies to stop the growth of gambling behaviour.

Challenges to Human Research

Human research into gambling behaviour meets many difficulties in real life situations. In order to design an appropriate experiment, it is important to manipulate and control all related environmental issues which the participant is exposed to (Weatherly, 2006). Researchers would like to control physiological or genetic issues (e.g. gender or age) of the participants, and they would like to manipulate the participants' previous experiences of reinforcement (Weatherly, 2006), however, this is not always possible. When conducting research studying human gambling behaviour, researchers will meet with many difficulties (Weatherly, 2006). Unless all of these control requirements as mentioned above (i.e. physiological and genetic issues that are controlled under research situations) could be manipulated appropriately, it is impossible to completely address ethical issues in human gambling behaviour research (Peters, Hunt, & Harper, 2010; Weatherly, 2006).

Fortunately, by using non-human animals to undertake studies of gambling behaviour, such difficulties could be overcome (Weatherly, 2006; Zentall, 2011). Given all these difficulties mentioned above, a very limited number of studies have investigated human participants in the gambling behaviour (Weatherly, 2006). Many researchers query the reliability and validity of an artificial replication of

human gambling behaviour (Weatherly, 2006). Therefore, more and more researchers are attempting to concentrate on developing animal analogue to mimic the human gambling behaviour procedures (Weatherly, 2006; Zentall & Laude, 2013). However, when using animal analogues to replace human research, researchers would meet new challenges which is how to get animals that do not normally gamble to do so.

Animal Suboptimal Choice Behaviour

Information Theory: From an information theory perspective, when reinforcement is provided or absent equally, the amount of effective transmission of information of the discriminative stimuli will affect the certainty of the reinforcement (Berlyne, 1957; Roper, 1999). For example, Roper and Zentall (1999) investigated pigeons' behaviour on two alternatives which were both associated with an overall probability of 50% reinforcement. In their experimental procedure, the pigeons were provided two white response keys to choose. The pigeons needed to peck on a key to gain food during the choice trials. The outcome after the subject pecked on a key was uncertain due to there was a 50% chance to get access to food or food absence. The probability of reinforcement associated with one of the alternative was changed from 50% to 100% reinforcement; the probability of reinforcement associated with another alternative was manipulated from 50% and decreased to 0%. (Roper, 1999). That means the reinforcement obtained of the alternative was manipulated from uncertainty to certainty. This is because, the pigeon would get food half time of the beginning of the experimental procedure when the alternative with a 50% probability of

reinforcement, but it would always get reinforcement or get nothing when the alternative with a 100% or 0% probability of reinforcement.

Information theory also suggests that when reliably signalled, the probabilities of discriminative alternative with equal occurrence, the effective information should be more than an unreliable alternative with the same 50% probability of reinforcement (Stagner, Laude, & Zentall, 2012). Thus, choosing the unreliable alternative with 50% probability of reinforcement will decrease as the improving uncertainty of this alternative (Roper, 1999; Stagner et al., 2012; Stagner & Zentall, 2010).

Observing Reponse: When behavior produces stimuli which help animals get reinforcement without changing the overall probability of reinforcement, this kind of behaviour is called *observing behaviour* (Roper, 1999). For example, pigeons behaviour of stepping on a treadle that would lead to a discriminative stimulus which showed the current schedule they are working on (Wyckoff, 1952). That means in this procedure, the pigeons would observe a stimulus which operated by their behaviour will produce a discriminative stimulus.

Animals' suboptimal choice behaviour is similar to human gambling behaviour, such as, playing a slot machine or buying lottery tickets. This is because, in both cases, participants overrate reward results. Many experimental studies are providing evidence for animal suboptimal choice. Including with rodents (Rivalan, 2009; Zeeb, 2009), dogs (K. F. Pattison, & Zentall, T. R., 2014), and birds (K. F. Pattison, Laude, & Zentall, 2013). For instance, prior research results supported that when pramipexole level increased, rats showed preference for a suboptimal choice option which is similar to human behaviour (Johnson et al., 2011).

Depending on foraging theory and reinforcement mechanisms, animals should not show suboptimal choice behaviour in a natural environment (Anselme, 2013; Zentall, 2011). Foraging theory supports that, in a natural environment, animals are always trying to enlarge their survival resources (e.g. food) with lowest cost (e.g. physical output) (Anselme, 2013; Bateson & Kacelnik, 1997; Zentall, 2011). Depending on the basic principles of reinforcement theory, organisms' behaviour should be strengthened or weakened by a certain stimulus (Skinner, 1938). Therefore, when organisms feel hungry their behaviour should express desire for food rather than choosing a suboptimal option with less food.

More recent literature showed that pigeons tend to show preference on a low-probability but high-payoff suboptimal alternative over a reliable low-payoff optimal alternative (Laude, Beckmann, Daniels, & Zentall, 2014; Laude, Stagner, et al., 2014; Stagner, Laude, & Zentall, 2011; Stagner et al., 2012; Stagner & Zentall, 2010). Laude, et al. (2014) manipulated the delay to food to test their hypothesis that long delays are associated with increasing suboptimal choice behaviour in pigeons. Their results showed that pigeons prefer a smaller-sooner or a larger-later alternative within a shorter delay (Laude, Beckmann, et al., 2014). That is to say the pigeons' choose suboptimal. This research finding can be applied to human gambling behaviour research and suggest that high levels of impulsivity can lead to acquisition of gambling behaviour (Laude, Beckmann, et al., 2014).

When providing two alternatives to pigeons, one which is a suboptimal option with 50% signal of presenting reinforcement, and the other which is an optimal option with 75% unsignal of presenting reinforcement, the pigeons showed an obvious preference for the suboptimal alternative (Gipson, 2009) . In

Gipson's (2009) procedure, if the pigeon pecked the left white response key, the key would be illuminated by a red or green color which is associated with 50% probability of reinforcement. The red key always lead to reinforcement and the green key always lead to a blackout time period. If the pigeon pecked the right white response key, the key would be illuminated by a blue or yellow color which was also associated with 50% probability of reinforcement, however, regardless of the alternative, there was always 75% probability reinforcement. In Gipson's (2009) experimental procedure, the left alternative is a suboptimal choice with less reinforcement (food), the right alternative is an optimal option with more reinforcement (food). Figure 1 shows the procedure of Gipson's experiment. Moreover, in this kind of experimental procedure, the red and green colors are generally called the discriminative stimuli as they provide distinguished chances of getting access to reinforcement or reinforcement absence, on the other hand, the blue and yellow colors are called the non-discriminative stimuli as both of them are associated with the same probability of getting reinforcement (Baum, 2005; Gipson, 2009; Stagner et al., 2011; Zentall, 2011).

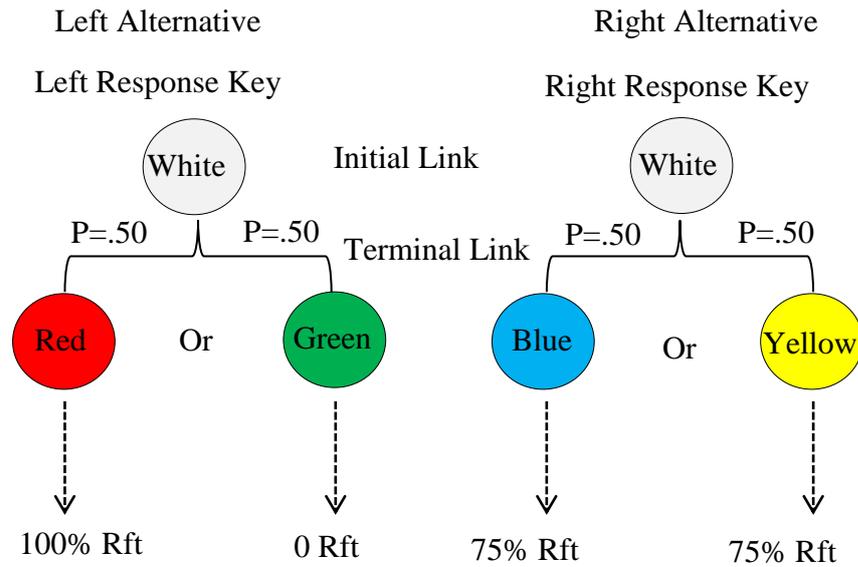


Figure 1. Gipson's (2009) experimental procedure. Both sides' alternatives show to each pigeon.

Stagner and Zentall (2011a, b) found that pigeons even show a significant preference for an alternative associated with 20% signal to reinforcement over an alternative associated with 50% unsignal reinforcement. Nonetheless, in Stagner and Zentall's (2011a, b) study, pigeons strongly prefer an alternative associated with a 20% probability of providing ten pellets of reinforcement (food), and a 80% probability of getting reinforcement absence, over an alternative with an average of three pellets of reinforcement. That means the pigeons prefer the suboptimal choice alternative where they could only receive an average of two pellets of reinforcement through experimental sessions (Zentall & Stagner, 2011a; Zentall & Staner, 2011b). These findings suggested that pigeons' preference for the suboptimal choice alternative was not because of the uncertain reinforcement of the optimal choice alternative (Zentall & Stagner, 2011a; Zentall & Staner, 2011b) as the researchers used a certain number of food pellets instead of an uncertain probability of reinforcement associated with the optimal option. Interestingly,

when the researchers changed the the discriminate stimuli (i.e. red/green color) to non-discriminative, for example, the suboptimal choice alternative associated with both 20% probability of reinforcement on red and green colors, the pigeons definitely preferred to choose the optimal alternative (Zentall & Stagner, 2011a; Zentall & Staner, 2011b).

Previous research (Gipson, 2009; Laude, Stagner, et al., 2014; Stagner & Zentall, 2010; Zentall, 2011; Zentall & Stagner, 2011a; Zentall & Staner, 2011b) showed that pigeons showed an obvious preference for a suboptimal option which was always reliably signaled by a pair of discriminative stimuli (i.e. red/green) over an optimal option which was always unreliably signaled by a pair of nondiscriminative stimuli (i.e. blue/yellow) (Zentall, 2011; Zentall & Laude, 2013; Zentall & Staner, 2011b). Especially, Zentall and Stagner (2011) found that when changing the discriminative stimuli to nondiscriminative, the pigeons tended to choose the optimal alternative. Depending on these results, the researchers concluded that pigeons actually prefer to choose a reliable signaled reinforcement rather than an unreliable signaled reinforcement (Stagner et al., 2011).

Animal Analogue of Gambling Behaviour in Current Research

So far in this thesis, the author has discussed gambling and problem gambling as areas that need to be researched, and also discussed animal behaviour and suboptimal responding which can be analogised to gambling. Zentall and his colleagues (2010) bring these two ideas together. According to most literature (Gipson, 2009; Roper, 1999; Stagner & Zentall, 2010), pigeons show a strong preference for a reliable suboptimal choice alternative which is

associated with a discriminative stimulus. In the current research, the author is interested to know if manipulating the discriminative stimuli from nondiscriminative to discriminative, will show if the birds generally prefer to choose the suboptimal alternative reliably. The current research will be based on Stagner and Zentall's (2010) research, which used different experimental phases to compare pigeons' preference on a significant signaled reinforcement alternative and an alternative with unsignaled reinforcement.

This current research has slightly modified Stagner and Zentall's (2010) experimental design with manipulating the probabilities of reinforcement associated to each discriminative stimulus. In Stagner and Zentall's (2010) experimental procedure, their first pretraining phase used a fixed-interval 10-s schedule to train pigeons to peck on four different colors which were red, green, blue, and yellow. The fixed-interval 10-s (FI) schedule is a procedure where reinforcement was provided after 10 seconds following the first response (Stagner & Zentall, 2010). The subjects (six roosters) of the current research were experimentally naive, therefore, in the current research all roosters needed to be shaped to peck on experiment keys at the very beginning. A continuous schedule of reinforcement (CRF) schedule was used to shape subjects to distinguish and peck correctly and reliably on response keys to get access to reinforcement. During the CRF procedure, the reinforcement will be provided instantly after pecking on the response key which have a coloured stimulus of either red, green, blue or yellow. Once all the subjects are pecking correctly and reliably on the response key during the CRF schedule procedure, they will move to the FI schedule procedure, after receiving reliable behaviour of the FI schedule procedure, the experiment will move on to the experimental conditions.

The current research designed the experimental conditions to manipulate the probabilities of reinforcement which are associated to the discriminative stimuli (a red or green colour) which signalled by the suboptimal alternative. At the very beginning of the experiment, the red or green stimulus was have the same probability of providing reinforcement. Therefore, the reinforcements followed each colour during suboptimal alternative trials are non-discriminative as the suboptimal choice. Throughout the different conditions of the current research, the reinforcements followed each colour during suboptimal alternative trials will be manipulated from non-discriminative to obvious discriminative. For example, in the first condition, the probability of reinforcement which is associated with each colour (red or green) will be the same 50%. In the following conditions, the probabilities of reinforcement which is associated with the red colour will be gradually increased from 50% to 100%. However the probabilities of reinforcement which is associated with the red colour will be gradually decreased from 50% to 0%.

Methods

Subjects

Six adult roosters (*Gallus gallus domesticus*), numbered 8.1 to 8.6, which were at least one year old before the experiments started, served as subjects. Each rooster was kept individually in home cages which were 620-mm high by 790-mm wide by 610-mm deep. Within the home cages, free access to water was provided. Birds received vitamin supplements and grit weekly. The home cages were located in a room with 12 hours of light and dark alternately. All birds were weighed daily and bodyweights were used to assess bird health. Birds were maintained at 80% ($\pm 5\%$) of their free-feeding bodyweights. The experimental procedure was approved by the Animal Ethics Committee of the University of Waikato (AECN: 918) and the birds were cared for following the animal care guidelines of the University of Waikato (Animal Welfare, 2010).

Apparatus

A particle-board chamber (620-mm \times 790-mm \times 610-mm) was used. There was a food hopper attached to the experimental chamber on one wall along with three round Perspex-response keys each 30-mm in diameter. These three response keys were centrally positioned on the response panel in a horizontal line 100-mm apart with a vertical distance from the chamber floor of 400-mm. Each key could be illuminated by white, red, green, blue or yellow by an LED bulb. Pressing any of the response keys, when illuminated, produced an audible beep. A white LED

bulb in the hopper opening was turned on during reinforcement. The experiment was controlled by Med-PCIV software through a Dell PC computer with a Windows XP system.

Procedure

Prior to each experimental session, each rooster in succession was moved from its home cage, weighted, put into the experimental chamber and then the experiment was started. Each experimental session, finished after 120 experimental trials or 60 minutes of session time, whichever occurred first. After each experimental session (i.e. 120 trials or 60 minutes), the data were recorded both by MED-PCIV and were written manually into a data book. Birds were returned to their individual home cages when the session finished.

Training Phases.

There were two training phases. The first one was a continuous schedule of reinforcement (CRF) phase and the second was a fixed-interval 10-s (FI) phase. During each CRF training trial, the middle key illuminated white while the side keys were dark. Once the bird had pecked the illuminated key, the middle key would randomly become either red, green, blue or yellow. After the bird pecked this coloured key, there was a 2-s access to reinforcement (wheat) provided. Figure 2 shows the procedure of the CRF phase.

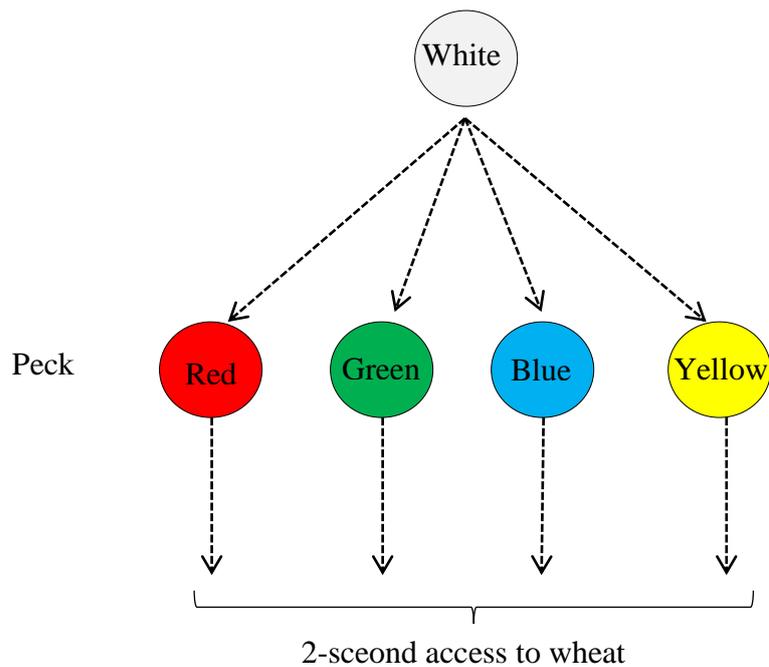


Figure 2. General procedure of CRF phase. One trial of the CRF phase presented a white key which when pecked, changed to a colour key of either red, green, blue or yellow. Once the bird pecked the coloured key, it received a 2-s access to reinforcement.

The fixed-interval 10-s (FI) phase procedure was the same as the CRF training procedure except that a FI 10-s schedule response requirement was used instead of a CRF schedule and a 10-s inter-trial interval (ITI), following each trial was implemented. Figure 3 shows the procedure of the fixed-interval 10-s (FI) phase.

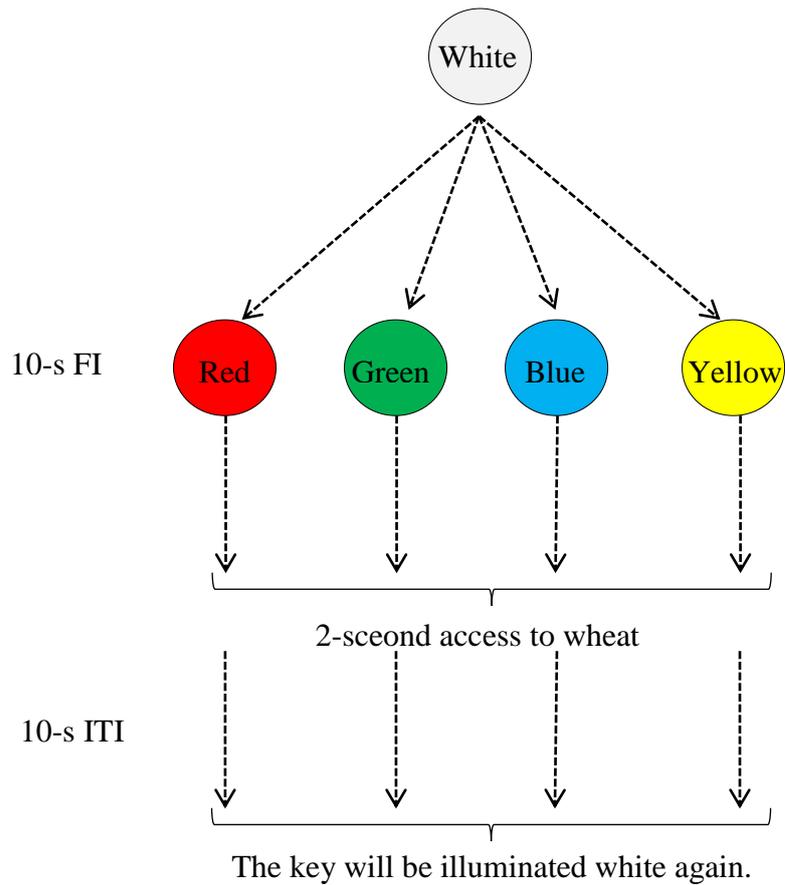


Figure 3. General procedure of FI 10-s phase. One trial of the FI phase, presented a white key which, when pecked, changed to a coloured key of either red, green, blue or yellow. Once the bird pecked the coloured key after the FI, they received a 2-s access to reinforcement, which was followed by a 10-s ITI.

Trial Procedure

Discriminated Stimulus Trials (Red or Green).

Each discriminated stimulus trial began with an illuminated white middle key. After the bird pecked the key, the left key was illuminated white, and after the bird pecked the left white key, it was then illuminated either red on 20% of occasions or green on 80% of occasions. Once the red or green key was pecked, the procedure would then move on to FI 10-s. After the FI 10-s the bird would get

a 2-s access to food reinforcement or a 3-s blackout time period. Across conditions on the red key, the probability of reinforcement was gradually increased (50%, 62.5%, 75%, 87.5%, and 100%). Meanwhile, across Condition 1 to Condition 5 on the green key, the probability of reinforcement was gradually reduced (12.5%, 9.4%, 6.3%, 3.1%, and 0).

Non-discriminate Stimulus Trials (Blue or Yellow).

Each non-discriminate stimulus trial began with an illuminated white middle key which once pecked, the right key was illuminated white. After pecking on the right white key, it would be illuminated by either blue or yellow. The blue was presented on 20% of trials, and the yellow was presented on 80% of trials. After the blue or yellow key was pecked, the procedure moved on to the FI 10-s. When FI 10-s finished, the bird would experience a 2-s access to reinforcement or a 3-s blackout time period. The non-discriminate keys (blue and yellow) both lead to reinforcement on 50% of trials and blackout time period on the other 50% of trials.

Experiment Procedure

There were 120 possible trials during each experimental session which lasted a maximum of 60 minutes (3600 seconds). Within the 120 trials, there were 40 forced left choice reinforcement trials, 40 forced right choice reinforcement trials, and 40 choosing trials. All three types of trials were presented randomly.

Forced Left Trials (Discriminate): Each forced left trial started with an illuminated white middle key. After the key was pecked, the left white key was

illuminated; once the bird pecked this key, the key was illuminated either red or green immediately. After pecking the response key (which was either colour red or green), the FI 10-s would start, and when the FI 10-s finished, this would lead to a 2-s access to reinforcement or a 3-s blackout time period. Providing reinforcement or reinforcement absence depended on the colour.

Forced Right Trials (Non-discriminate): Each forced right trial started with an illuminated white middle key, after pecking it this would lead to a white right key, which once the bird had pecked on it, would be illuminated either blue or yellow immediately. After pecking the response key (which was either colour blue or yellow), the FI 10-s would start. When the FI 10-s finished, this would lead to a 2-access to reinforcement or a 3-s blackout time period. Again providing reinforcement or reinforcement absence depended on the colour.

Choice Trials: Each choice trial started with an illuminated white middle key, and after the key was pecked both the side keys would be illuminated white immediately. Once the bird pecked either of the sides, the response key would illuminate with an associated colour (red, green, blue or yellow), and the other side key would become dark. After pecking the response key, a FI 10-s would start. When the FI 10-s finished, a further peck would lead to a 2-s access to reinforcement or a 3-s blackout time period.

Experiment Conditions

Conditions 1-5.

In these five conditions, the reliability to predict reinforcement delivery of the discriminative stimulus in the terminal link was manipulated systematically. Table 1 illustrates the probability of presenting different coloured stimuli and the times of reinforcement (reinforcement probability) corresponding to each stimulus across the conditions. Figure 4 shows the procedure of the experiment and the probability of reinforcement associated with each colour stimulus.

Table 1. *Order of experimental Condition 1 ~5: the probability of presenting different colours and the times of reinforcement corresponding to each stimulus.*

No. of Condition	Left Alternative		Right Alternative	
	Discriminate Alternative		Non-Discriminative Alternative	
	Probability of Each Colour (%)	Times of Reinforcement of Each Colour	Probability of Each Colour (%)	Times of Reinforcement of Each Colour
	Red/Green	Red : Green	Blue/Yellow	Blue : Yellow
Condition 1	20/80	4:4	20/80	4:16
Condition 2	20/80	5:3	20/80	4:16
Condition 3	20/80	6:2	20/80	4:16
Condition 4	20/80	7:1	20/80	4:16
Condition 5	20/80	8:0	20/80	4:16

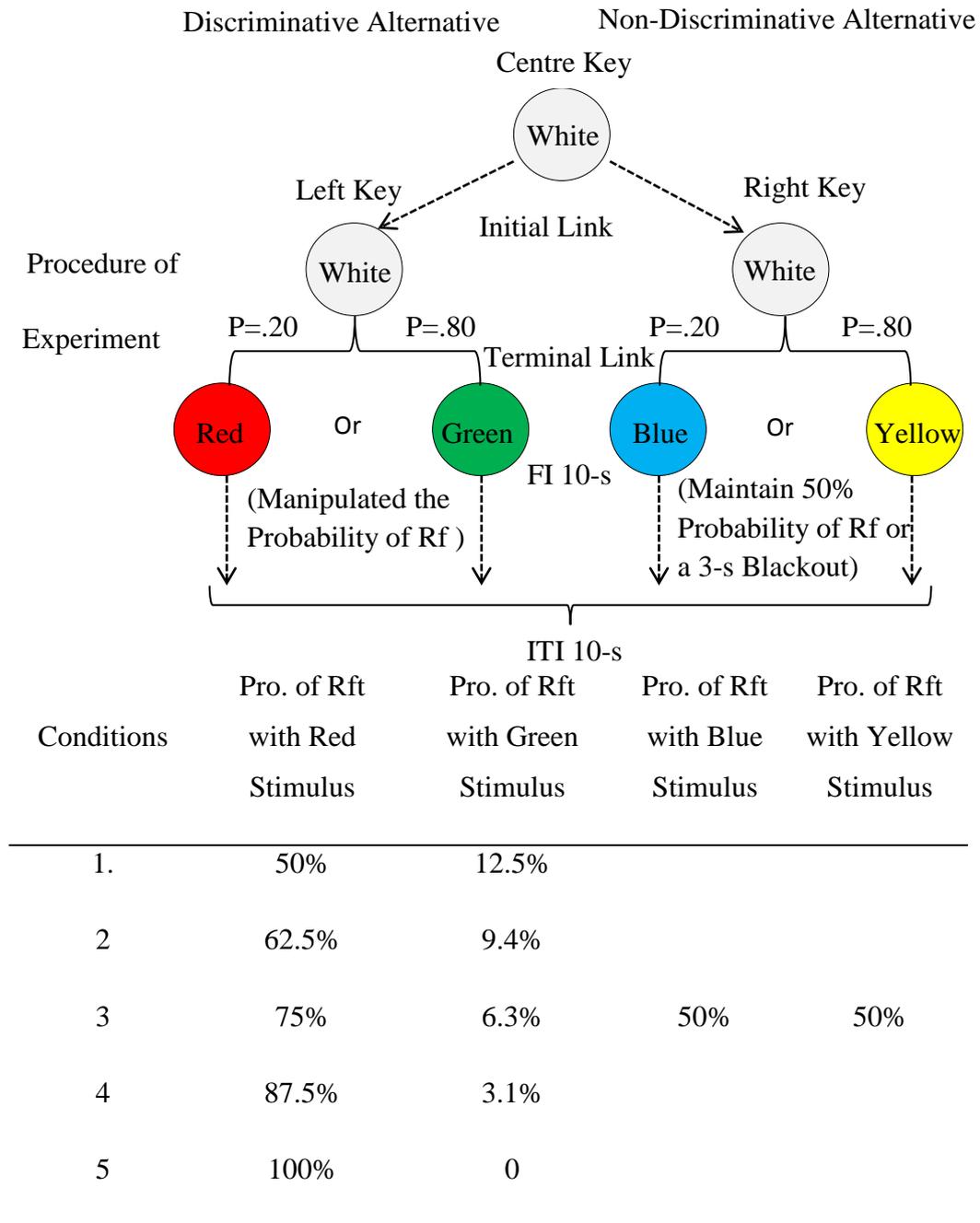


Figure 4. Diagram of the procedure of the experimental and reinforcement (Rft) magnitude associated with each colour stimulus.

Replication Procedure

To investigate the reliability of the birds' performance through Condition 1 to Condition 5, a replication of each of these five conditions was carried out. The same six roosters experienced the same five conditions when they completed the first five conditions. The sessions of the replication procedure were designed the same as the first five conditions.

Results

All of the birds completed two sessions on a continuous schedule of reinforcement (CRF) and two sessions on a Fixed-Interval 10-s (FI) schedule. Table 2 shows the numbers of sessions that each bird completed for each condition. The birds completed different numbers of sessions in each experimental condition due to a range of non-experimental factors. Rooster 8-4 died during Replication Condition 3 and rooster 8-2 was removed during Replication Condition 5 due to poor health. The final data analysis used the first 20 sessions of each experimental condition for each bird. Rooster 8-2 and 8-4's data was used where available. All of the statistical analysis was carried out using IBM SPSS Statistics (Version 19) software.

The probability of choosing the suboptimal alternative was the dependent variables of the current research. Figure 5 illustrates session by session performance for all conditions and their replications for each rooster. The horizontal axis shows the experimental sessions for each day, the vertical axis shows the percentage of choices for the suboptimal alternative of each rooster. The solid lines represent roosters' percentage of suboptimal choice through the first five conditions. The dotted lines show roosters' percentage of suboptimal choice through the replication conditions. The long dotted reference lines which are perpendicular to the horizontal axis represent the shift between conditions through the first five conditions. The short dotted reference lines represent the shift between each condition of the replication procedure. Some of the vertical dotted lines do not overlap as different birds completed different numbers of

sessions throughout the first five experimental conditions and the replication conditions.

Table 2. *The number of sessions completed within each experimental condition.*

Conditions	Roosters					
	8-1	8-2	8-3	8-4	8-5	8-6
Condition 1	20	20	20	20	20	20
Condition 2	20	20	20	20	20	20
Condition 3	23	21	20	20	21	23
Condition 4	22	20	24	20	20	22
Condition 5	21	20	20	20	20	20
Replication Condition 1	25	25	25	25	25	25
Replication Condition 2	20	21	20	20	20	20
Replication Condition 3	20	20	20	17	20	20
Replication Condition 4	20	20	20	-	20	20
Replication Condition 5	22	12	21	-	21	20

Results of the Conditions One - Five

As shown on Figure 5, four of the six roosters' behaviour (8-1, 8-4, 8-5, and 8-6) is suboptimal by the end of the fifth experimental condition, as the data showed a trend from low to high rates of suboptimal choice. Roosters 8-4, 8-5, 8-6 behaved optimally through the first three conditions then became suboptimal during Condition 3. Rooster 8-1 behaved variably at the beginning of experimental sessions and his behaviour became increasingly suboptimal during

Condition 1. Roosters 8-2 and 8-3 did not show sub-optimal choice behaviour instead they tended to choose the optimal alternative overall.

A one-way ANOVA with repeated measures was conducted to compare the effect of suboptimal choice within the different conditions (Condition 1 to Condition 5) of each subject. A significant main effect of the first five conditions was found on rooster 8-1, $F(4, 16) = 26.66$, $p = 0.00 < 0.01$; rooster 8-2, $F(4, 16) = 12.70$, $p = 0.00 < 0.01$; rooster 8-4, $F(4, 16) = 122.32$, $p = 0.00 < 0.01$; rooster 8-5, $F(4, 16) = 1699.17$, $p = 0.00 < 0.01$; and rooster 8-6, $F(4, 16) = 752.08$, $p = 0.00 < 0.01$. However, there was not a significant main effect of conditions on rooster 8-3, $F(4, 16) = 1.19$, $p = 0.35 > 0.01$. Therefore, overall, all the subjects' suboptimal choice behaviour was changed significantly throughout the first five conditions, except rooster 8-3.

A one-way ANOVA with repeated measures was conducted to compare the effect of suboptimal behaviour through all the first five conditions with all the six subjects pooled. The result indicates that the roosters showed a significant difference: $F(4, 116) = 56.88$, $p = 0.00 < 0.01$, of their suboptimal choice behaviour through Condition 1 to Condition 5.

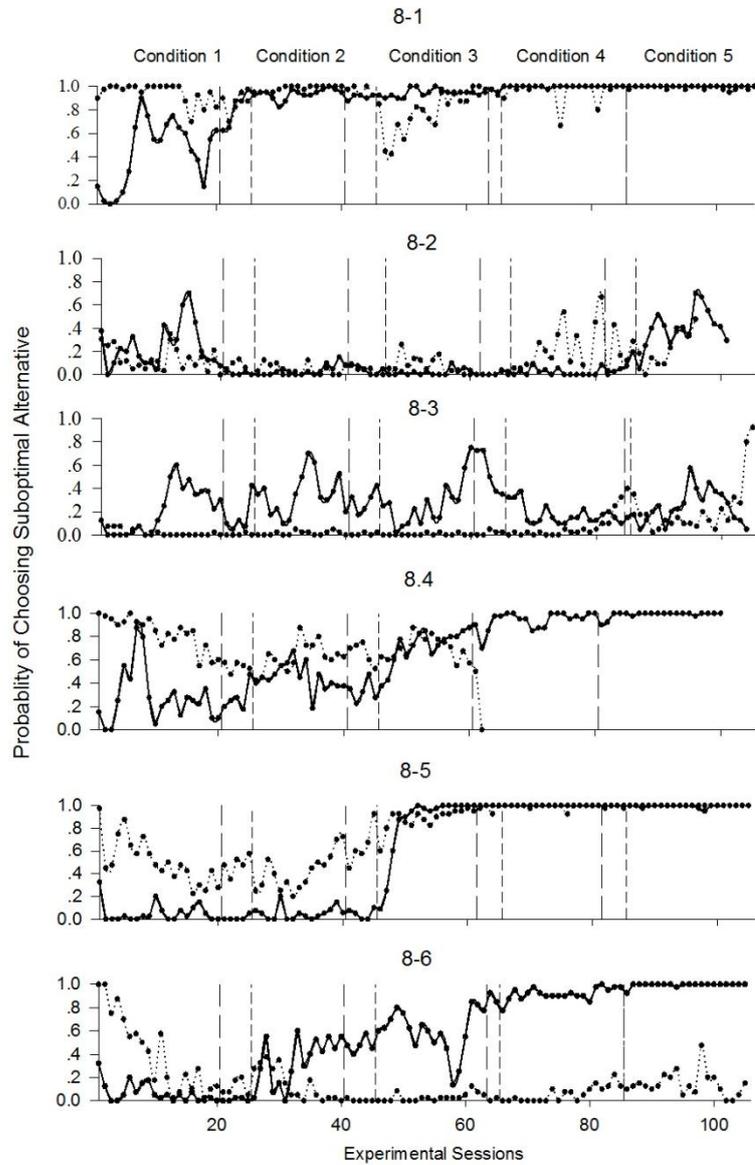


Figure 5. Raw experimental data. The horizontal axis shows the experimental sessions (day by day); the vertical axis shows the percentage of choosing the suboptimal alternative (i.e. left key). Two data paths in each graph illustrate two series of conditions. The vertical long dotted lines separate each condition through the first five conditions. The vertical short dotted lines separate each condition through the replication conditions. These vertical dotted lines did not totally match due to the roosters completing different numbers of sessions through each experimental condition.

Results of Replication Conditions

As shown in Figure 5, during the replication conditions procedure, rooster 8-1 showed suboptimal choice behaviour from the beginning of Replication Condition 1, and then his probabilities of choosing suboptimal choice behaviour became variable during the last one third of this condition. However, his behaviour went back to suboptimal responding during Replication Condition 2, and then became variable again during Replication Condition 3, and his behaviour changed to be suboptimal at the end of Replication Condition 3. Rooster 8-2 and 8-3 presented almost optimal choice behaviour through replication conditions, but rooster 8-2's behaviour became variable during Replication Condition 4. Rooster 8-3's behaviour became variable during Replication Condition 5 and had achieved a peak of choosing for the suboptimal choice alternative by the end of this condition. Rooster 8-5 showed variability through the first three replication conditions, however, his behaviour changed to suboptimal during Replication Condition 3 which is similar to that showed during his prior Condition 3. However, during the replication conditions procedure, rooster 8-6 behaved opposite to his behaviour in prior conditions. Through the first five conditions, rooster 8-6's behaviour started to show suboptimal responding during Condition 3, however, through the replication conditions procedure, his behaviour showed a gradual change from suboptimal to optimal.

The same ANOVA was carried out for this replication data as done previously. A significant main effect of the replication conditions was found on rooster 8-1 as well, $F(4, 16) = 15.98, p = 0.00 < 0.01$. Only the first four conditions data of the replication procedure were analysed for rooster 8-2; his

behaviour showed significant main effect: $F(3, 17) = 17.98, p = 0.00 < 0.01$. A significant main effect of the replication conditions was found in rooster 8-3: $F(4, 16) = 6.21, p = 0.03 < 0.01$. Rooster 8-3's behaviour changed obviously through the replication conditions. Figure 5 shows that at the end of Replication Condition 5, his behaviour changed sharply from choosing a suboptimal alternative. With the missing data, rooster 8-4's suboptimal behaviour still shows significant effect through the effective data he had completed: $F(2, 14) = 24.15, p = 0.00 < 0.01$. A significant main effect of the replication conditions was found with rooster 8-5: $F(4, 16) = 211.36, p = 0.00 < 0.01$; and with rooster 8-6 as well, $F(4, 16) = 17.70, p = 0.00 < 0.01$.

However, due to the missing values of rooster 8-2 and 8-4 through the replication conditions, a one-way ANOVA with repeated measures was not conducted for all the six roosters.

Discussion

The purpose of the current research was to investigate if systematically manipulating the probabilities of reinforcement associated with the discriminative stimuli would cause the roosters' behaviour to change from optimal to suboptimal. Throughout the first five conditions, most roosters' behaviour showed a trend from optimal to suboptimal as the probability of choosing the suboptimal option was increased (e.g. as low as 0 during the first two conditions, as high as 100% during the last three conditions). When the stimuli which was associated with suboptimal alternative changed from non-discriminative to obviously discriminative, four of the six roosters' response probabilities of choosing the discriminative alternative changed from low to high. In other words, four of the six roosters tended to show a preference for choosing the alternative with an overall 20% probability of reinforcement over an alternative associated with an overall 50% probability of reinforcement through the first five conditions. One rooster's behaviour switched during Condition 1. Three of the roosters' behaviour switched from optimal to suboptimal during Condition 3. These results were partly consistent with Stagner and Zentall's (2010) research results.

During the first five conditions, four of the subjects' behaviour moved from being non-gambling like to gambling like. Especially, when the different probabilities of reinforcement for each discriminative stimulus were distinguished, the roosters' suboptimal choice behaviour was more obvious. In other words, four of the six roosters showed strong suboptimal choice behaviour during Condition 5, in which the discriminative stimuli were associated with 100% reinforcement of the red stimulus and 0 reinforcement of the green stimulus. This result was

consistent with Stagner and Zentall's (2010) research results in which pigeons showed preference for a discriminative alternative with an overall 20% probability of reinforcement over a non-discriminative alternative with an overall 50% probability of reinforcement. Furthermore, two of the roosters showed optimal choice behaviour throughout Condition 1. This result also matches that of Zentall and colleagues' research results in that when there is a suboptimal alternative with non-discriminative stimuli, the pigeons showed a strong preference for choosing the optimal alternative (Zentall & Stagner, 2011a; Zentall & Staner, 2011b).

Some roosters showed both preferences for the suboptimal alternative during Condition 5 and for the optimal option during Condition 1. This situation may support the information theory (Berlyne, 1957) which argues that the subject's preference for the alternative should depend on how much effective information was transmitted. When an alternative with obvious discriminative stimuli are associated with 100% reinforcement or reinforcement absence, the signal which leads to a discriminative stimulus transmitted the largest amount of information (a red colour always lead to reinforcement, but a green colour always lead to nothing). On the other hand, when an alternative with a same 50% probability of reinforcement was associated with two different colours (i.e. blue/yellow), where either of each colour will lead to 50% reinforcement or 50% blackout time period the information transmitted unclearly with both the non-discriminative stimulus.

However, in spite of the commonality seen with Stagner and Zentall's (2010) work, the results of the first experiment cannot reliably support Stagner and Zentall's (2010) research conclusion due to the contrary patterns seen in the roosters' behaviour. Besides the four roosters' suboptimal choice behaviour, one

rooster showed almost optimal choice behaviour through Condition 2 to Condition 4. Another one's behaviour was totally varied throughout the whole first five conditions. These results are inconsistent with information theory. This is because, in Condition 1, the effective information was with the lowest value, but the rooster showed preference for choosing the suboptimal option. Information theory cannot explain the reason for a rooster's varied behaviour through Condition 1 to Conditions 5 as Condition 1 had the lowest amount of effectively transmitted information but Condition 5 had the largest effective information.

The results of the replication conditions seemed the opposite to the results seen for the conditions. Figure 5 showed that only two roosters showed similar behaviour to that of the first five conditions. These results cannot support Stagner and Zentall's (2010) research finding. One rooster whose behaviour showed a suboptimal trend through the first five conditions showed totally optimal choice behaviour through the replication conditions. Overall, three of the six roosters' behaviour showed optimal choice trend during the replication procedure. These results do not support Stagner and Zentall's (2010) research or information theory.

In conclusion, Stagner and Zentall's (2010) animal analogue does not seem to succeed as an accurate reference to be used to study human gambling behaviour. Their research results were not replicated by the current model. Moreover, there was no reliable point in time when the subjects' behaviour switched from optimal to suboptimal. At this time, it is still unclear what might give rise to gambling like behaviour in both human and non-human organisms. Therefore, further research to develop animal analogue to investigate human gambling behaviour is required.

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