The Effects of Food Deprivation on Memory Performance

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1 Abstract

Previous research has noted that pigeon weights fluctuate over a calendar year with birds being heavier during the winter than the summer months. Given that food deprivation can be a motivator of behaviour, it is possible that the fluctuations in animals' weights might impact performance in operant research, for example accuracy in a DMTS memory task. The effects of two different amounts of food deprivation on roosters performance in a delayed matching-to-sample (DMTS) procedure was measured. There were two conditions 75% and 95% ad libitum free feeding body weight. I attempted to assess whether a lower body weight produces more correct responses in a DMTS procedure. The results indicated that the roosters performed better when less food deprived. The last 10 sessions and the last 400 trials of both conditions was used to describe the memory performance and accuracy. There was a significant difference in the slope of the forgetting function when comparing the two conditions for the last 10 sessions, with no significant differences in the intercept. For the last 400 trials there was no significant difference for the slope or intercept when comparing the two conditions. A ceiling effect was seen to occur with some of the birds. The results from some of the roosters suggest that improved performance might occur due to exposure to the task. More accurate remembering occurred when the roosters changed from one condition to the other condition, suggesting that repeated exposure to the task increased memory performance and accuracy.

2 Acknowledgements

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6 Literature review

6.1 Delayed matching-to-sample task

The delayed matching-to-sample (DMTS) experiment was designed by Blough in the late 1950s (Blough, 1959). He used an operant chamber with three keys side by side, which could be illuminated. After presentation of the sample stimulus, which was a flickering or steady white light on the centre key, there was a delay. After the delay, the keys on either side of the centre key were illuminated representing either the flickering or steady option. One side key matched the sample, and the other did not. Food was given when the pigeon pecked the key that matched the stimulus presented on the middle key before the delay (Blough, 1959). As time increased between stimulus presentation and the opportunity to respond, the percentage of correct responses decreased. When there was no delay between stimulus and the opportunity to respond, there was a consistently high percentage of correct responses - around 90% correct (Blough, 1959).

Blough's (1959) procedure was considered a measure of short-term memory. Response accuracy after different delays in the DMTS procedure can be plotted as a graph with a best fit curve. This best fit curve has been referred to as a *forgetting function*. The slope of the forgetting function shows the rate of forgetting over temporal distance or delay. The fitted forgetting function tends to show that the shortest delay produces the most accurate responses and the longest delay the least accurate responses. The gradient can be a very steep slope where performance drops sharply (e.g. Kendrick et al., 1981; Sargisson & White, 2003b; Weavers et al., 1998) or a shallow slope with a small difference between the accuracy of recall across the delays (e.g. Harper, McLean & Dalrymple-Alford, 1994; Sargisson & White, 2003a).

The procedure has been used with human participants (e.g. Adamson, Foster & McEwan, 2000; Chelonis, Daniels-Shaw, Blake & Paule; 2000; Reed, 2012; Yang, Chiu & Yeh, 2012) and non-human animals such as monkeys (e.g. Buccafusco, Terry Jr, Vazdarjanova, Snutch, & Arneric, 2010; Harper, 2011; Harper, et al, 1994; Reynolds & Medin, 1979; Terry Jr, Buccafusco, Borsini, & Leusch, 2002; Worsham, 1975).

However, a majority of the large body of research using the DMTS procedure has been with avian species, particularly pigeons (e.g. Alsop & Jones, 2008; Calder & White, 2014; Goto & Watanabe, 2009; Hunt, Parr & Smith, 1999; Jones & White, 1992; Kendrick, Tranberg & Rilling, 1981; Macdonald, 1993; Spetch & Rusak, 1989;).

6.2 Food deprivation

Food deprivation is a common practice in operant experiments to incite motivation to produce behaviour (Makowiecki et al., 2012). Research with and focused on food deprivation has been ongoing since the 1950s (Bare, 1958; Bokkers, Koene, Rodenburg, Zimmerman & Spruijt, 2004; Bokkers, Zimmerman, Rodenburg, Koene, 2007; Bolles, 1958; Bolles & Petrinovich, 1956; Ehrenfreund, 1958; Ghent, 1951; Ghent, 1957; Jones & Rogers, 2003; Komaki, 2004; Oliveira, Calvert, Green, & Myerson, 2013; Pierce, Diane, Heth, Russell, & Proctor, 2010; Sargisson, McLean, Brown, & White., 2007; Treichler & Hall, 1962).

Bokkers et al. (2004) tested broiler chickens at 50% and 75% of their ad libitum body weights with a progressive ratio schedule. The question was whether the different states of deprivation would have an effect on their performance on a progressive ratio schedule for a food reward. They found that the more highly deprived chickens would pay a higher maximum response requirement than the least deprived. Thus, a higher deprivation level with these birds would show that they would respond more to receive a food reinforcement. However, these authors did not test the accuracy of memory performance at different deprivation levels. While the birds may be more motivated to work for food when hungrier, it is unclear whether an increased response rate will predict improved memory performance.

Oliveira et al. (2013) researched pigeon's responses to delay discounting procedures with two different states of food deprivation. The effect of deprivation on choices with pigeons may show the strength of a reward. The pigeons discounted rewards when the delay was longer as is typical of the delay discounting theory. This suggests the performance of the pigeons in a delay discounting experiment was the same whether they were deprived of food or whether they were not deprived of food.

Nikendei et al. (2011) researched the memory abilities of patients with anorexia nervosa. They found the memory of the participants with anorexia nervosa was impaired; suggesting that at extreme levels of starvation, the ability to perform tasks that require memory may be limited.

Landers, Arent, and Lutz (2001) researched the consequences of rapid weight loss on the short-term memory of college-age wrestlers. Landers et al. (2001) did not find cognition to be greatly affected. There were correlations between rapid weight loss and reaction time as well as positive and negative affect (Landers et al., 2001). The weight variations suggest that there is a consequence to going down to a lower weight in a short space of time, but that rapid weight loss may not affect remembering accuracy.

Jones and Rogers (2003) looked at cognitive functioning during food deprivation and after consuming food. The process of dieting was thought to have an adverse effect on cognitive processes. The participants performed cognitive-based tasks and were interviewed for their thoughts about the tasks, how they performed, and why they think they performed as they did. The research determines that there are other factors in effect (Jones & Rogers, 2003). The distraction of an intervening variable such as food-orientated thoughts could reduce processing abilities and the ability to process a number of functioning operations at the same time (Jones & Rogers, 2003).

Nikendei et al. (2011), and Pierce et al. (2010) found an effect on memory recall when working with food-deprived participants. White (2012) also showed that distraction on working memory may make storage of items harder and adjusting the level of distraction appears to have an effect on recall. Makowiecki et al. (2012) found that mice that were deprived to 80% of their free-feeding body weight learned a Y maze faster, and to a higher level of accuracy than a group deprived to 90%. Thus, a higher level of food deprivation was found to be advantageous to learning and performance.

6.3 Prior research forming this study

Sargisson, et al. (2007) suggested that seasonal fluctuations may have an effect on the memory performance of pigeons. The researchers reported that birds were heavier in the winter months and lighter in the summer months (Sargisson et al., 2007). They found that a higher level of food deprivation produced more accurate memory performance from pigeons (Sargisson et al. 2007). Sargisson et al. (2007) also considered how the pigeons may have recognised the change in seasons. The rooms which housed the pigeons were kept at a temperature ranging between 17-19° C throughout the year. But there were frosted windows which allowed natural light to enter the home cage room. This was possibly how pigeons recognised seasonal change, as clearly it could not be a temperature difference (Sargisson et al., 2007). During the winter months, the pigeons produced more accurate remembering data (Sargisson et al., 2007). This was a time when the pigeons were assumed to be at a higher state of deprivation. When the pigeons are motivated by a higher state of food deprivation, the performance accuracy on the DMTS task increased (Sargisson et al., 2007). Sargisson et al. (2007) maintained pigeons at one food-deprived weight over a full calendar year.

6.4 The forgetting function

Accuracy of remembering at different temporal distances between a stimulus and the opportunity to remember that stimulus can be plotted on axes and displayed as a curve function, called a *forgetting function*. This forgetting function illustrates, by way of a fitted curve, the decay of memory over different lengths of time (Bayliss & Jarrold, 2015; Bilodeau, Jones & Levy, 1964; Brown & White, 2005a; Jones, O'Gorman & Byrne, 1987; Kanungo & Das, 1960; MacDonald, 1993; Murayama, Miyatsu, Buchli & Storm, 2014; Noreen & Macloed, 2013; Ortega, Gómez-Ariza, Román & Bajo, 2012; Sargisson & White, 2007; Sargisson et al., 2007; Slamecka & Katsaiti, 1988; Slamecka & McElree, 1983; White & Ruske, 2002; Wilson, 1943; Wixted, & Ebbesen ,1991; Underwood & Keppel, 1963). Figure 1 is a fictitious example of a forgetting function that shows a gradual decline in remembering over increasing delays.

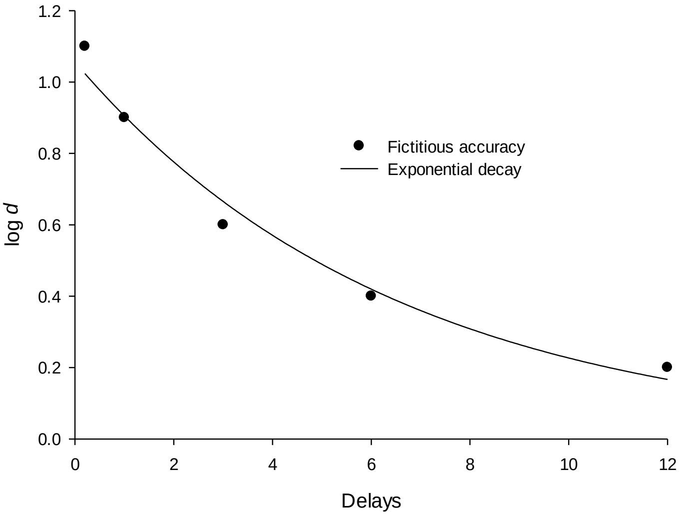

Figure 1. Example of forgetting function with hypothetical delay accuracy declining over increasing delays and an exponential curve best fit to the data points.

The forgetting function is useful to show the decay of memory over temporal distance. The mathematical functions that are consistent with transforming raw data to a fitted function are exponential, power, logarithmic, and hyperbolic (White, 2001). In the present study, I used log *d* (Equation 1) to transform responses and to avoid ceiling effects.

$$\text{Log } d = 0.5 * \log\left(\left(\frac{\text{cred}}{\text{ered}}\right)\left(\frac{\text{cgreen}}{\text{egreen}}\right)\right) \qquad \text{Equation 1}$$

Where c = correct and e = error, and red and green refer to the key colours used.

From the curve, the rate of forgetting over delays (slope), and initial discriminability in the absence of a delay (intercept) can be derived. DMTS data can be used to produce a forgetting function where the smallest delay is usually associated with the most accurate response and the largest delay the least accurate. The gradient can be very steep, where performance drops sharply reflecting greater forgetting during increasing periods between exposure to the sample and choice. The opposite, where there is a shallow slope reflects maintenance of high rates of remembering over increasing delay.

6.4.1 Intercept change

Manipulating variables has been shown to affect the intercept of the forgetting function (Foster, Temple, MacKenzie, DeMello & Poling, 1995; White, 1985). Brown and White (2005a) studied differential attention to the sample in a DMTS task with pigeons. They presented a signal for the magnitude and the probability of the reinforcer after a sample light had been extinguished. The results suggested accuracy can be influenced by discrimination and reinforcement contingencies (Brown & White, 2005a). Brown and White suggest that when the stimulus is gone, the participant may recall more accurately providing there is a bigger payoff. They found the slope of the forgetting function remained the same, it was the intercept that changed (Brown & White, 2005a).

Sargisson et al. (2007), found that the pigeons in their experiment either decreased their accuracy or remained constant with one pigeon increasing their accuracy towards the end of the allocated research time length. The calendar year for this experiment started in and ended in the summer months. During the summer, the pigeons when held at 85% of a free feeding weight were thought to be at a lower state of food deprivation. This shows that accuracy remained stable during either state of food deprivation.

Weavers, Foster, and Temple (1998) delayed reinforcement for hens responding in a DMTS task. When reinforcement is delayed, if remembering is still accurate it suggests that remembering is not reliant on continuous immediate reinforcement. A delay to reinforcement decreased accuracy at all delays, resulting in a change in the intercept, but not the slope of the forgetting function (Weavers et al., 1998).

White (2013) reviewed remembering and the effect of manipulating variables within experiments on the slope and the intercept of the forgetting function. Variations to the sample stimuli affect the intercept forgetting function curve separately from the slope (Roberts 1972; White, 1985).

The research described above suggests that if the reinforcement contingencies are not manipulated and the sample stimulus is consistent there will be no significant change in the intercept. However, increasing the value of the reinforcer to an animal by decreasing its bodyweight (increasing food deprivation level) may improve accuracy at all delays, which would be seen as an increase in the intercept of the forgetting function.

6.4.2 Slope change

The research of (Sargisson et al. 2007), reported that the slope of the performance for 4 of the pigeons showed a decrease towards the winter season and increased in the summer season. This produced a u shaped performance across the whole calendar year. One pigeon decreased their performance over the calendar year. These pigeons were kept at a constant weight throughout the research with winter intending to be a time of greater food deprivation. The results for (Sargisson et al. 2007) show that the rate of forgetting is less when the pigeons were more food deprived with the slope being shallower during winter, than at the summer time.

The increase or decrease in accuracy with increasing temporal delay from stimulus presentation and the opportunity to respond is illustrated by the slope of the forgetting function. The accuracy of recall of the stimulus usually decreases as the delay increases between the presentation and the opportunity to respond (Kendrick et al., 1981). A decrease in the slope of the forgetting function reflects a shallower slope. A shallow slope will show that accurate performance is maintained over longer temporal delays. An increase in the slope reflects a steeper curve. A steeper curve will show decreasing accuracy over longer temporal delays.

Illumination of the experimental chamber during the delay has been found to cause a matching inaccuracy with pigeons (Kendrick et al., 1981). Kendrick et al. (1981) found constant illumination to produce the highest discriminability in pigeons. There was shown to be no significant difference between different illumination sequences such as, when the chamber was a mixture of light and dark; either when the illumination was during the inter-trial interval or during the sample presentation. Kendrick et al. (1981), showed that there was no change in the intercept, however, there was an increase in the slope when there was a light inter-trial interval and a light stimulus presentations compared to the last three session blocks of a dark inter-trial interval and light stimulus presentation.

Buccafusco et al. (2010) researched the effect of neuropathic pain treatment on memory functions with monkeys. Amytriptyline and Gabapentin are commonly used market medications. The effect of these drugs on cognitive abilities, specifically memory, was examined with non-human primates in a DMTS task. Adult macaques performed a DMTS task after receiving medication at 30 min or 24 hours prior to starting the DMTS task. There were three delay groups of short, medium, and long. Each macaque had an individual setting of seconds for each delay group. Some medical treatments can be linked to memory, verbal recall, and attention and some have been seen to improve cognitive functions. The researchers showed an improvement in memory performance with certain dosage levels and times between administration and the trial, resulting in a shallower slope, but no change in intercept. So, generally, variables such as drug dosage and events that occur during the retention interval to disrupt remembering have been shown to affect the slope of the forgetting function rather than the intercept.

7 Memory accuracy and performance for this thesis

In this thesis, I present research on the effects of food deprivation and memory performance with roosters. My thesis was a quantitative study of memory performance of birds with two different food deprivation levels. One deprivation level was considered to be a low level of deprivation and the other to be a high level of deprivation. The deprivation levels are explained more in the procedure sub-section of the Method section. The purpose of this experiment was to extend the research by Sargisson et al. (2007). By manipulating two food deprivation levels, I was attempting to see if the memory accuracy and performance would show similar results as Sargisson et al. (2007). I attempted to mimic the seasonal effect by maintaining two set weight conditions during a pre-set number of sessions for a DMTS task procedure.

Operant procedures tend to maintain research animals at a lower body weight than may be considered a normal weight for that animal naturally (Makowiecki, Hammond, & Rodger, 2012). Food serves as a reinforcer for a food-deprived animal. In operant research, where food is commonly used as a reinforcer for responding, the standard procedure is to deprive animals of food to ensure that animals will work to receive it (Makowiecki et al. 2012; Sargisson et al. 2007; Skinner, 1953).

An animal will work less for a reinforcer, or not at all, when satiation occurs (Skinner, 1953). The level of deprivation as seasons change could affect motivation to perform a task, these cyclic weather changes may affect the behaviour (Skinner, 1953). Thus the performance of the animal may be affected by the state of food deprivation; contingent with a calendar season when the experiment is conducted, which has an effect on the data and results produced by the experiment (Makowiecki et al. 2012; Sargisson et al. 2007; Skinner, 1953).

In the current experiment, I did not directly manipulate the magnitude of reinforcement, which was the same for each delay. However, at higher deprivation levels, the same amount of reinforcement may be more valuable to the birds than when they are at lower deprivation levels. If this is the case, memory performance may be enhanced under higher deprivation levels, resulting in a change in intercept, but not slope – an improvement in accuracy with all delays – as seen in Brown and White's (2005a, 2005b, 2009) research articles.

8 Hypothesis

I hypothesised that forgetting functions resulting from the birds' performance on the DMTS task would be higher and shallower when the subjects are in a higher state of deprivation, showing that remembering remains accurate as delay increases. This result would suggest that weight can be a confounding variable in experiments that use food-deprived animals.

9 Method

9.1 Subjects

The subjects were six roosters; four experimentally experienced roosters numbered 3-6 and two naïve roosters 1-2. They were housed in individual cages measuring approximately 500mm in width and depth; the top three cages were approximately 400mm in height and the bottom three cages were approximately 860mm in height. The larger of the roosters were kept in the larger three cages. They had free access to water. They were also given supplementary vitamins and food pellets to maintain their health whilst working at the desired weight ranges for the experiment. Refer to Appendix A for ethical approval and extension information.

Bird 5 died after completing the 95% condition and was replaced by Bird 7 who started in the 75% condition.

The birds' ad-libitum body weights were established after a period of free-food access (2-3 weeks) prior to the training schedule before the first experimental conditions began. The free-feeding weights were established in the early spring. Each bird was maintained at each weight in each condition through increasing or decreasing supplementary food, dependent on the amount of reinforcement they received. Birds 1, 3, and 5 started in the 95% condition and Birds 2, 4, and 6 started in the 75% condition. The birds earned the majority of their food during an experimental session and were given supplementary food as required to maintain their body weights within the desired range. The birds were only included in an experimental session if their weight fell within the prescribed weight range.

Experimental sessions occurred 7 days a week, and were run at about the same time each day. Birds were run in the same order each day. At the end of an experimental session, the roosters were returned to their home cages.

9.2 Apparatus

The apparatus was an operant chamber (shown in Figure 2) approximately 1190mm wide, 750mm high, and 530mm deep.

Figure 2. Operant chamber for DMTS experiment.

The chamber had three response keys in a horizontal row on one internal wall of the chamber. The keys were 32mm in diameter, 430mm from the bottom of the chamber, 535mm from the top of the chamber, approximately 60mm apart and 130mm from the right wall and 120mm from the left wall. The keys were made of a clear hard plastic approximately 3mm thick. The response keys could be illuminated by1-W red and green lights. The key required a force of no less than 0.2N to record a response. There was a hopper feeder which supplied 3-s access to wheat when correct responses were made. The feeder had an infrared beam so that the 3-s access to wheat did not start until the bird had put his head into the hopper. The hopper was approximately 115mm from the floor of the chamber and 135mm in height and 100mm wide. The hopper had a white light illuminated when reinforcement was available. The chamber was controlled by a Med-PC computer programme.

9.3 Procedure

Following training (see below) the birds started in one of the two conditions: In the 95% condition, a DMTS task was performed by the birds at a low level of food deprivation (95% ± 2.5% of free feeding body weight) and in the 75% condition the same DMTS task was performed at a high level of food deprivation (75% ±2.5% of their free feeding body weight). Appendix B gives detail on the weight recording. I planned for all of the birds to participate in both conditions, with three birds participating in the 95% condition first and three birds participating in the75% condition first. The birds changed conditions when they had completed 50-55 sessions in the previous condition.

9.3.1 DMTS training.

Each bird was trained on the DMTS task with a 0-s delay until it achieved 80% or more correct responses over five consecutive sessions. In DMTS training, a trial began with the centre key lit either red or green. After five pecks on the centre key, the centre key light was extinguished. After a delay of 0 s, one side key was lit red and the other green. When the bird pecked the key that matched the colour that was illuminated in the centre key, it received 3-s access to wheat immediately. When the bird pecked the key that did not match the colour that was previously presented in the centre key the chamber went into a blackout for 2-s. When the bird was achieving consistently 80% correct with 0-s delay, it then began the experimental condition.

9.3.2 Experimental condition.

The DMTS task the birds experienced in the experimental condition was consistent with the research by Sargisson et al. (2007). I used the same programme with the same delays, reinforcement allocations, and time lengths between trials, reinforcement and maximum session times as in the original programme used by Sargisson et al. The experimental session began with 10 pre-trials that were not included in subsequent data analysis. The basic procedure is as described above, except that a full set of delays of 0.2, 1, 3, 6, and 12 seconds were programmed and the birds were deprived to either 95 or 75% of their free-feeding body weight as per their assigned condition. There were a total of 81 trials per session or 40 minutes, whichever occurred first. When the bird had completed 50-55 experimental sessions they commenced the opposite food-deprivation condition with the same DMTS task.

9.3.3 Data analysis

With the size difference between the pigeons in Sargisson et al. (2007), and the birds in this research, the magnitude of the access to reinforcement may have contributed to the birds regularly being over the 2.5% variance of the target weight. In the early stages of the experimental process, it was not uncommon for the birds to participate for a small consecutive number of days, then to be outside the weight range and to take a number of days to come back down in weight. This contributed to irregular running of the experimental sessions on consecutive days, and incomplete sessions for some birds.

Due to the fact that birds sometimes failed to complete sessions, and that sessions were run infrequently and non-consecutively, response data for each individual bird, and for the mean across birds, were analysed in two ways; for the last 10 sessions of each condition, and for approximately the last 400 trials of each condition. This ensured a comparison between data from the *same* number of *sessions* with *different* numbers of *trials* (the 10-session analysis), and a *variable* number of *sessions* but the *same* number of *trials* (the 400-trial analysis).

I used Microsoft Excel 2013® to sum number of correct red, correct green, error red, and error green responses made by each bird with each delay. I used the response totals to calculate log *d* (Equation 1) from approximately the last 400 trials of each completed condition, and from all trials from the last 10 sessions of each completed condition.

Log *d* was plotted and Sigma plot 12.5® was used to fit an exponential decay, single, 2-parameter curve using Equation 2 and provide the R^2, *a* (intercept), and *b* (slope). The exponential decay curve is the forgetting function for each condition.

$$y=ae^{-bx} \qquad \text{Equation 2}$$

10 Results

Bird 1 was naïve to an experimental chamber and, after successive attempts to hand shape, reshape, and train the required behaviour, this bird would not perform. I decided to change Bird 1 into the 75% FF BW condition as he was not responding under the 95% FF BW conditions. He did begin to regularly complete the set number of trials when deprived to 75% of his FF bodyweight and completed the 50 sessions in the 75% condition, but did not participate any further due to time constraints. Because there are no comparative data from both conditions, the results for Bird 1 will not be presented.

Response data were converted to a measure of accuracy (log *d*) using Equation 1 and plotted in Figure 3 for both the last 10 sessions (left panel) and for the last 400 trials of each condition (right panel). Forgetting functions were fitted to the log *d* data using Equation 2. Parameters for the fitted functions (slope and intercept) and the percentage of variance accounted for (R^2) are shown in Tables 1 (for the last 10 sessions) and 2 (for the last 400 trials).

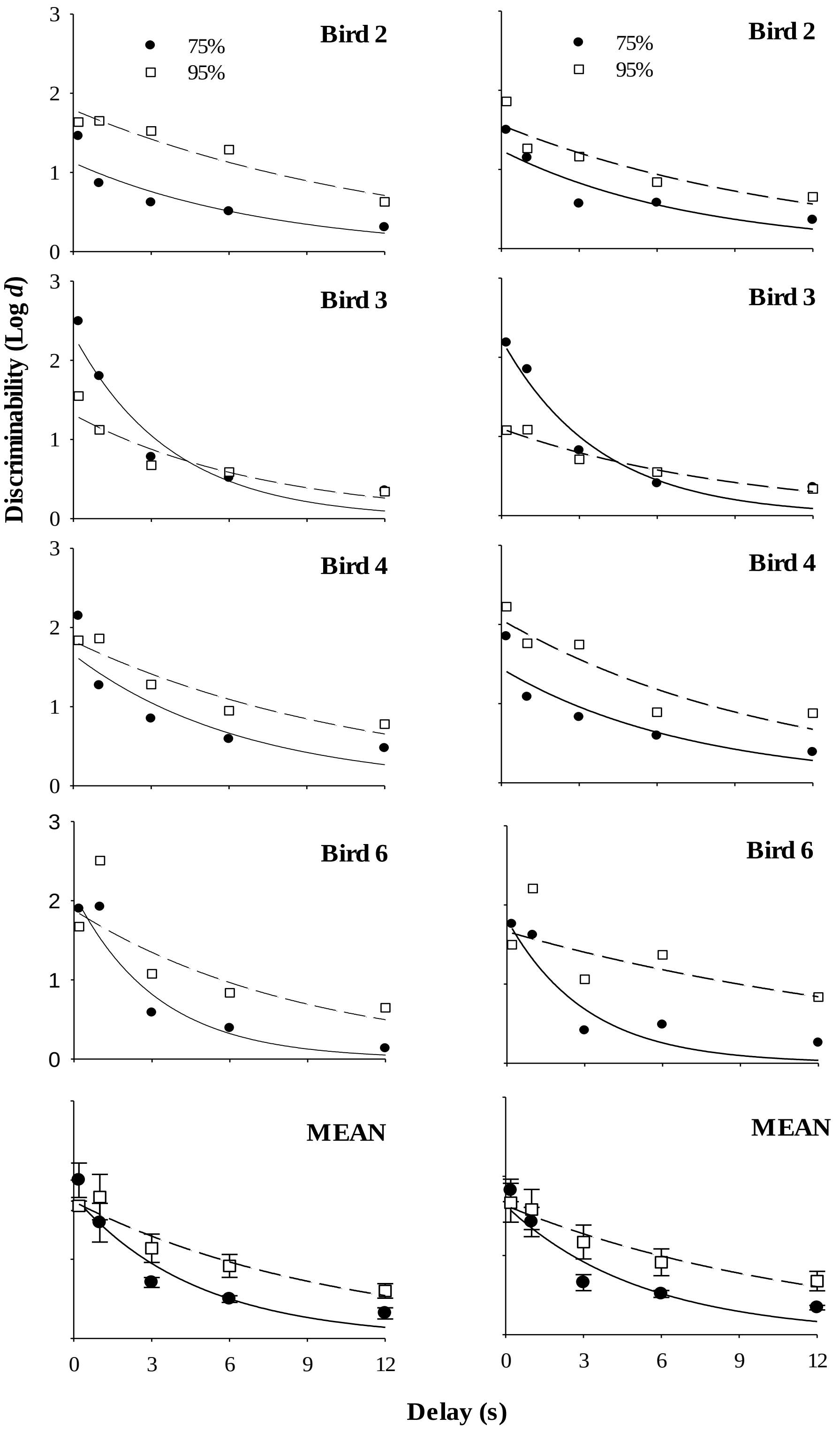

Figure 3. Discriminability (log d) as a function of delay for Birds 2, 3, 4, 6 and the mean across birds for the 75% condition (filled circles, solid line) and the 95% condition (open squares, dashed line) for the last 10 sessions (left) and approximately the last 400 trials (right) of each condition. Error bars on the mean graph show the standard error of the mean across birds.

Table 1

Parameter values from Lines Fitted using an Exponential Decay, Single, 2 Parameter Function; Namely, R^2, a (intercept), and b (slope) for the 75% and 95% Conditions and the Mean Across all Birds from the Last 10 Sessions.

Bird	Condition	R^2	*a*	*b*
2	75%	0.82	1.13	0.13
	95%	0.94	1.79	0.08
3	75%	0.87	2.32	0.26
	95%	0.87	1.32	0.13
4	75%	0.77	1.66	0.15
	95%	0.90	1.83	0.09
6	75%	0.92	2.08	0.31
	95%	0.70	1.88	0.11
Mean	75%	0.88	1.79	0.21
	95%	0.94	1.73	0.10

Table 2

Parameter values from Lines Fitted using an Exponential Decay, Single, 2 Parameter Function; Namely, R^2, a (intercept), and b (slope) for the 75% and 95% Conditions and the Mean across all Birds from the Last 400 Trials Approximately.

Bird	Condition	R^2	*a*	*b*
2	75%	0.77	1.24	0.13
	95%	0.85	1.56	0.08
3	75%	0.89	2.23	0.27
	95%	0.96	1.10	0.11
4	75%	0.84	1.44	0.14
	95%	0.82	2.06	0.09
6	75%	0.72	1.82	0.33
	95%	0.53	1.66	0.06
Mean	75%	0.84	1.63	0.19
	95%	0.95	1.63	0.08

For Bird 2, the intercept (a) was higher when the bird was in the heavier 95% condition ($a = 1.79$) as shown in Table 1, than when in the lighter 75% condition ($a = 1.13$). Table 2 shows a similar effect with the 95% condition producing a higher intercept ($a = 1.56$) than the 75% condition ($a = 1.24$). Tables 1 and 2 show that the slopes (b) are similar for each condition (75% condition; $b = 0.13$, 95% condition; $b = 0.08$), for both analyses. The higher the slope (b), the steeper the curve, and the faster the forgetting over temporal distance. The closer to 1 the R^2, the better the fit of the forgetting function. For Bird 2, the R^2 values were all reasonably high, showing that the exponential fit was a good representation of the data.

The data for Bird 3, in Tables 1 and 2, show the intercept (*a*) was higher in both analyses in the 75% condition compared to the 95% condition. The slope (*b*) shown in Table 1 for the last 10 sessions was steeper for the 75% condition (b = 0.26) and shallower for the 95% condition (b = 0.13). Table 2 shows the same pattern of slopes (*b*) for the 400-trial analysis (75% condition; b = 0.27, 95% condition; b = 0.11). The R^2 shown in Tables 1 and 2 for Bird 3 were all over .85.

Table 1 shows Bird 4 had a better initial accuracy when less deprived with an intercept (*a*) for the 75% condition of 1.66 and for the 95% condition of 1.83. The intercept (*a*) for the last 400 trials shown in Table 2 showed the same pattern as the 10-session analysis. The data for Bird 4 produced a slightly steeper slope (*b*) for the 75% condition (b = 0.15) compared to the 95% condition (b = 0.09) as shown in Table 1. Table 2 shows the similar effect with the 400-trial analysis. The R^2 for Bird 4's fits show that the fitted line was a good reflection of the data.

Table 1 shows that Bird 6's intercept was higher for the 75% condition (a = 2.08) compared to the 95% condition (a = 1.88). The same pattern was shown in the 400-trial analysis. The slope (*b*) for Bird 6 for the last 10 sessions for the 75% condition (b = 0.31) was steeper than that for the 95% condition (b = 0.11) with a similar pattern in the 400-trial analysis. The R^2 for Bird 6's exponential fits were not as high as the other birds across all of the conditions and session data analysed.

The mean analysis showed similar patterns regardless of whether the analysis was of the last 10 sessions or the last 400 trials. The mean intercept was higher and the slope steeper in the 75% condition. The R^2 for each of the conditions show a high goodness of fit for both the 95% condition and the 75% condition. This means the mean forgetting function curve for both conditions was an accurate reflection of the data.

Overall, for three of the four birds, and the mean, it appears that accuracy was higher when birds were less food deprived (heavier). For Birds 2 and 4, the slopes (rate of forgetting) were similar in the two conditions, but the intercept was higher in the 95% condition. For Bird 6, the intercepts were the same in the two conditions, but the 95% condition produced a shallower slope, meaning the performance dropped more quickly across increasing delay in the 75% condition. Bird 3 showed a faster rate of forgetting, and higher intercept under the 75% condition, showing that initial remembering was more accurate, but accuracy dropped more quickly with increasing delay in the 75% condition compared to the 95%.

Four *t* tests for dependent means was calculated using the data from the four birds to test for a significant difference between the 75% and the 95% conditions for both the intercept and the slope for each analysis method (400 trials and 10 sessions).

The *r* values, a measure of effect size, were calculated using Equation 3.

$$r = \sqrt{\frac{t^2}{t^2 + df}} \qquad \text{Equation 3}$$

The *t* test for the slope using the last 10 sessions showed it to be significantly steeper for the 95% condition, $t(3) = 3.35$, $p = .04$, $r = .89$. There were no other significant differences with any of the other three comparisons, showing that the intercept did not differ in the two conditions, and that no difference in slope was found using the 400-trial analysis.

In order to ascertain whether the order in which the birds experienced the two food-deprivation conditions affected accuracy in the two conditions, data were analysed for Birds 4 and 6 who repeated the 75% condition (Figure 4). The results shown in Figure 4 suggest that Bird 4's remembering accuracy may have been improving over repeated attempts. The intercept shown in Table 3 and Table 4 for Bird 4 are both higher and the slope for Bird 4 shallower under the second 75% condition than under the same weight condition when it was first experienced. However, while the accuracy of Bird 6 (Tables 3 and 4 and Figure 4) improved in the repeated 75% condition relative to the first, it was still less accurate overall than in the 95% condition. Figure 4 shows the mean for Birds 4 and 6 which also suggests an improvement from the first 75% condition to the second 75% condition, but that accuracy was still lower in the second 75% condition compared to the 95% condition.

When comparing the last 10 sessions of all conditions, Bird 4 may have reached peak performance. Bird 4's repeated 75% condition performance was very similar to his 95% performance as shown in Figure 4. Therefore, it is possible that any difference shown earlier in the two deprivation conditions was a function of experience with the task, rather than the deprivation level, and with further practice, the effect of deprivation disappeared. The results for Bird 6 still suggest that this bird performs better when at a lower deprivation level, as with continued experience with the task, performance dropped when the deprivation level increased again to 75%.

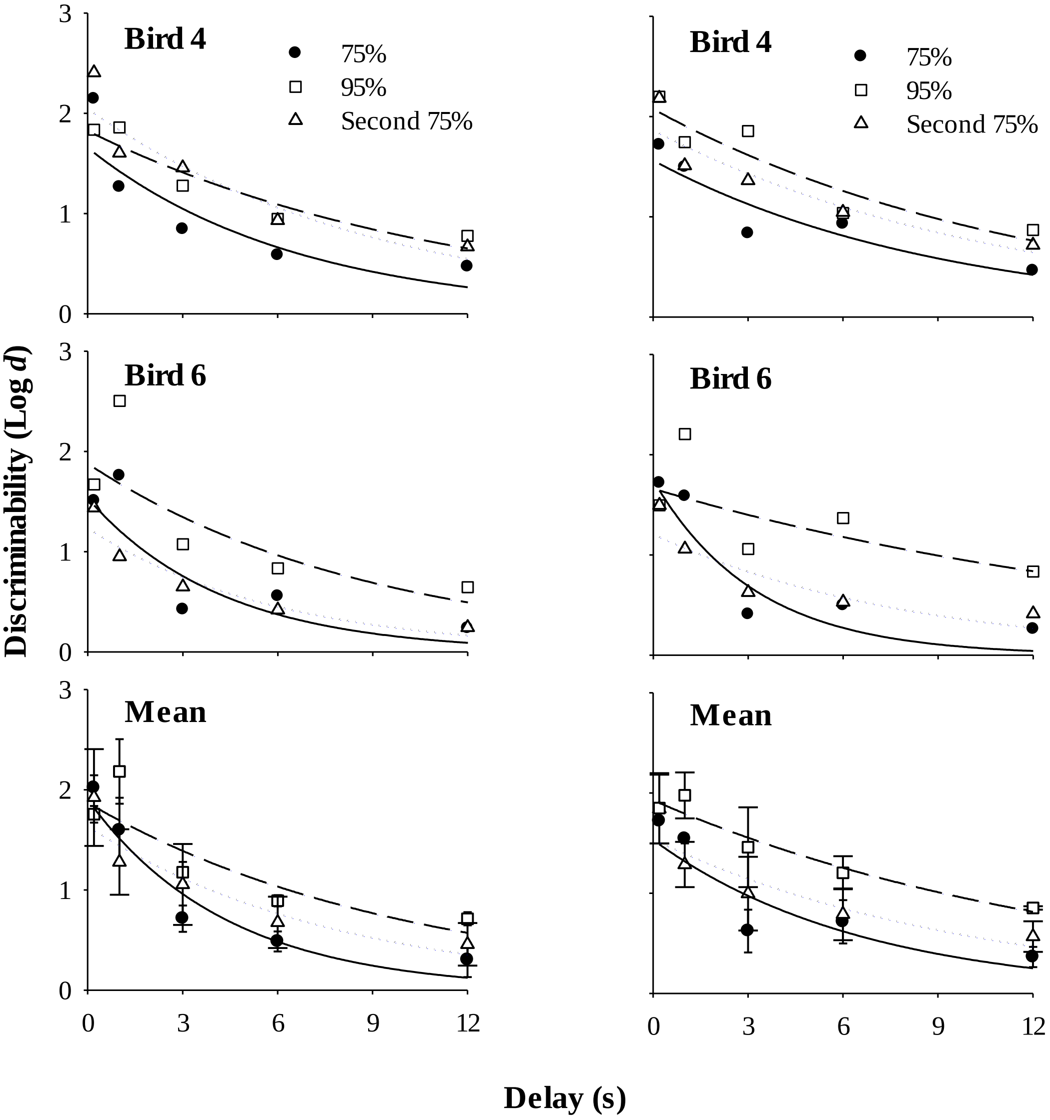

Figure 4. Discriminability (log d) as a function of delay for Birds 4, 6 and the mean across birds for the 75% condition (filled circles, solid line), the 95% condition (open squares, dashed line) and the second 75% condition (open triangles, dotted line) for the last 10 sessions (left) and approximately the last 400 trials (right) of each condition. Error bars on the mean graph show the standard error of the mean across birds.

Table 3

Parameter values from Lines Fitted using an Exponential Decay, Single, 2 Parameter Function; Namely, R^2, a (intercept), and b (slope) for the 75% and 95% Conditions and the Mean across Birds 4, 6 from the Last 10 Sessions.

Bird	Condition	R^2	*a*	*b*
4	75%	0.77	1.66	0.55
	95%	0.90	1.83	0.09
	Repeat 75%	0.89	2.04	0.11
6	75%	0.67	1.53	0.23
	95%	0.70	1.88	0.11
	Repeat 75%	0.92	1.24	0.17
Mean	75%	0.89	1.90	0.23
	95%	0.81	1.87	0.10
	Repeat 75%	0.90	1.63	0.13

Table 4

Parameter values from Lines Fitted using an Exponential Decay, Single, 2 Parameter Function; Namely, R^2, a (intercept), and b (slope) for the 75% and 95% Conditions and the Mean Across birds 4, 6 from the Last 400 Trials Approximately.

Bird	Condition	R^2	*a*	*b*
4	75%	0.86	1.56	0.11
	95%	0.87	2.08	0.08
	Repeat 75%	0.89	1.85	0.09
6	75%	0.71	1.75	0.31
	95%	0.53	1.66	0.06
	Repeat 75%	0.76	1.21	0.12
Mean	75%	0.78	1.53	0.15
	95%	0.96	1.93	0.07
	Repeat 75%	0.86	1.54	0.10

11 Discussion

Three of the four birds (Birds 2, 4, and 6) all performed better when in the less-deprived condition. This is counter to the hypothesis that forgetting functions resulting from the birds' accuracy on the DMTS task will be higher and shallower when the subjects are in a higher state of food deprivation. This is also counter to the results from Sargisson et al. (2007), where the pigeon's performance was found to produce shallower forgetting functions during the winter when they should have been in a higher state of deprivation.

One reason for this result could have been the order in which the birds participated in the two conditions; deprivation level may have been confounded with continued learning of the task over time. All three birds for whom performance was better in the less deprived condition started in the high-deprivation condition and then moved to the low-deprivation condition. Birds 4 and 6 repeated the high-deprivation condition, the results of Bird 4 supported the conclusion that performance improved over time, rather than as a function of deprivation.

Kangas, Berry & Branch (2011) reported their research on extended exposure to trials with the DMTS task; to show that the pigeons increased the initial accuracy at 0 s delay, as the session number increased. With a total of 300 sessions in this experiment, Kangas et al. (2011) found that the log *d* forgetting function showed across most birds to increase as exposure to the task increased. Also a negative exponential function of the intercept and slope, showed that across most birds, there was a clear increase in the intercept accuracy and an improvement in the slope. Kangas et al (2011), report that a steady state of improvement in a standard DMTS procedure can be seen when there is a high number of sessions. The number of sessions in my experiment was 100-110 sessions, as well as training which the number of sessions was determined by the subject reaching 80% correct for five consecutive sessions. This number of sessions is represented by Kangas et al. (2001), in their research as a session number where the accuracy and performance was steadily increasing.

Another suggestion was that the birds were in the least-deprived condition during the winter months. In a non-food-deprived state, the birds would be naturally heavier in winter. The deprivation level of 95% FF BW may have actually been greater than the arranged 95% level during the winter, as the birds would naturally gain extra weight over winter, and, instead, were prevented from doing so. This may have resulted in them being more motivated to acquire food during this season, and more food deprived in reality than was arranged. Food was only given in the experimental session when the response was correct, which may have resulted in more accurate responses at this time and in this condition.

Bird 3, who started in the least-deprived condition, did not regularly or consistently complete all of the trials. Bolles (1962) and Bolles and Petrinovich (1956) suggest that weight loss may be needed to produce behaviour if the reinforcers are food and Bokkers et al. (2004) showed that a hungrier bird would perform longer than a less-deprived bird. Bokkers et al. (2007) reported that a hungrier bird will physically walk longer to receive a food reinforcement than a less-deprived bird. When Bird 3 was placed in the less-deprived condition he ran less often, usually due to being over the maximum weight range. Bird 3 was given supplementary food to maintain his weight on days he did not run or receive a minimum amount of reinforcement. Providing food outside of the experimental session may have created a situation where it was not required that he complete all of the trials as he would be compensated with supplementary food after the session or when he did not run. A situation where reinforcement is available outside the experimental session is referred to as an "open" economy, and can be contrasted with a "closed" economy, where all reinforcement must be earned within the experimental session (Killeen, 1995; Ladewig, Sorensen, Nielsen &

Matthews, 2002). It is possible that in my experiment, which ran an open economy, the demand for the food had become elastic (Killeen, 1995). The elasticity of the reinforcement means that, as the experimental session progressed, the demand for food decreased. However, the other birds, who were also strictly operating within an open economy, completed all of the trials in the session time, displaying an inelastic demand for the reinforcement. This was an open economy even though these birds did not usually receive post-session feed because all the trials were completed due to the food reinforcement being available outside of session times.

Bird 1, who began participating in 95% deprivation condition, was naïve to the experiment and an experimental chamber. His pecking behaviour appeared to go into extinction in the early stages of training. I used a VR3 schedule to bring back the pecking behaviour, however, the bird again ceased to respond on the 95% deprivation condition. I changed the bird into the 75% of ad libitum body weight group in an attempt to get him working. The bird began to respond in this condition. The behaviour of Bird 1 in the 95% condition could also be explained by Bolles and Petrinovich's (1956) and Bokkers et al.'s (2004) research. When Bird 1 was at the higher food-deprivation level, this bird regularly began to respond in the task. Pierce et al.'s (2010) research also suggests that when food is in lean supply the body weight of the organism will provide enough sustenance until food can be acquired. When Bird 1 would not perform in the experimental chamber, his weight was maintained by a large amount of post feed, based on the small number of reinforcers acquired in the chamber. Makowiecki et al. (2012) considered behavioural learning to be affected by weight and motivation for hunger. Given that Bird 1 was naïve to experimental chambers and conditions, the learning of the behaviour may have required a higher level of motivation which may be the reason that he began to perform when in a more deprived state.

It is interesting to note that during the early stages of the weight manipulation, the seasons were changing from spring to summer. The ad libitum free feeding body weights were calculated during early spring as planned and during the course of the first month of summer, most of the birds were consistently outside the weight requirement. As it got further into summer, some of the birds' weights dropped sharply and also hovered just below the minimum weight requirement. This drop in weight during the change of season could show how summer is associated with weight decreases. The winter season had an effect in the other direction. It was harder to maintain the birds at a lower weight level during this season. Other researcher have found that there are biological changes to weight due to environmental conditions (Clark, 1979; Haftorn, 1989; Henry & VanCamp, 1979).

12 Limitations

The order that Birds 2, 4, and 6 completed the conditions has suggested that there may be a learning effect masking the effect of the body-weight manipulation, in that remembering performance generally improved over repeated exposure to the task irrespective of the body-weight condition. The performance of Birds 2, 4, and 6 was better in the second condition, which happened to be the less-deprived condition, 95% of their FF BW. However, the performance of Bird 6 dropped again in the third condition (75%) while that of Bird 4 remained high. These inconclusive results with such a small number of subjects makes it difficult to conclude whether there was continual learning and mastering of the task or whether there was an effect of food deprivation. My research design was initially counter-balanced such that Birds 1, 3, and 5 would begin with the less-deprived (95%) condition, and Birds 2, 4, and 6 would begin in the more-deprived condition (75%). However, Birds 1, 3, and 5 all encountered problems during the experimental phase. Bird 1 would not perform in a low-deprived state, and was changed to a higher-deprived state which he did complete. Bird 3 could not maintain weight to successfully complete the 95% condition and fell short of the 50-55 sessions required for the 95% condition. Bird 5 completed the 95% condition before dying, therefore, there were no comparison data and so his data were not included in the results. Bird 7 did not finish either condition and this bird's data were also not included as there was no comparison data to analyse. Therefore, while it was my intention to balance for order effects, this was not achieved. Future researchers could attempt to better balance conditions so as to eliminate the confounding variable of order. Weight is a difficult variable to manipulate, however, as it is slow to change, so must be manipulated across rather than within sessions. Future researchers might instead consider manipulating behavioural economies, such that no food is available outside the session, and short-term food deprivation levels rather than weight as a way to investigate the effects of motivation for food on remembering accuracy.

13 Conclusion

With the different results from Sargisson et al. (2007), it is difficult to determine whether the deprivation level has a predictable effect. The different species, environment, and weight conditions have added to the discussion. There were some clear differences in this thesis research and the previous research. What could be said is that there are seasonal variables which could have influenced the results. In the summer months, it was difficult to keep the birds at the lower deprived target weight, and during the winter it was difficult to keep the birds at a higher deprived target weight. The results show learning of the task over time, as well as a ceiling effect. This situation was unavoidable as the birds needing to complete both conditions in a consecutive order, and it is difficult to manipulate weight rapidly.

My research has provided some evidence that deprivation is required to produce behaviour in operant experiments. Many researchers (e.g. Bokkers et al. 2004; Bolles & Petrinovich, 1956; Makowiecki et al. 2012; Oliveira et al. 2013; Pierce et al., 2010) have found that deprivation level can be an important factor in the participant completing a task.

In my research, I used a DMTS task to test memory accuracy with roosters in two different states of deprivation. A higher level of accuracy was found when the birds were in a less-food-deprived state. Seasonal change throughout a calendar year had an effect on weight, which fluctuated, but no conclusion can be reached about whether remembering performance is affected by body weight due to the influence of the order of conditions experienced here.

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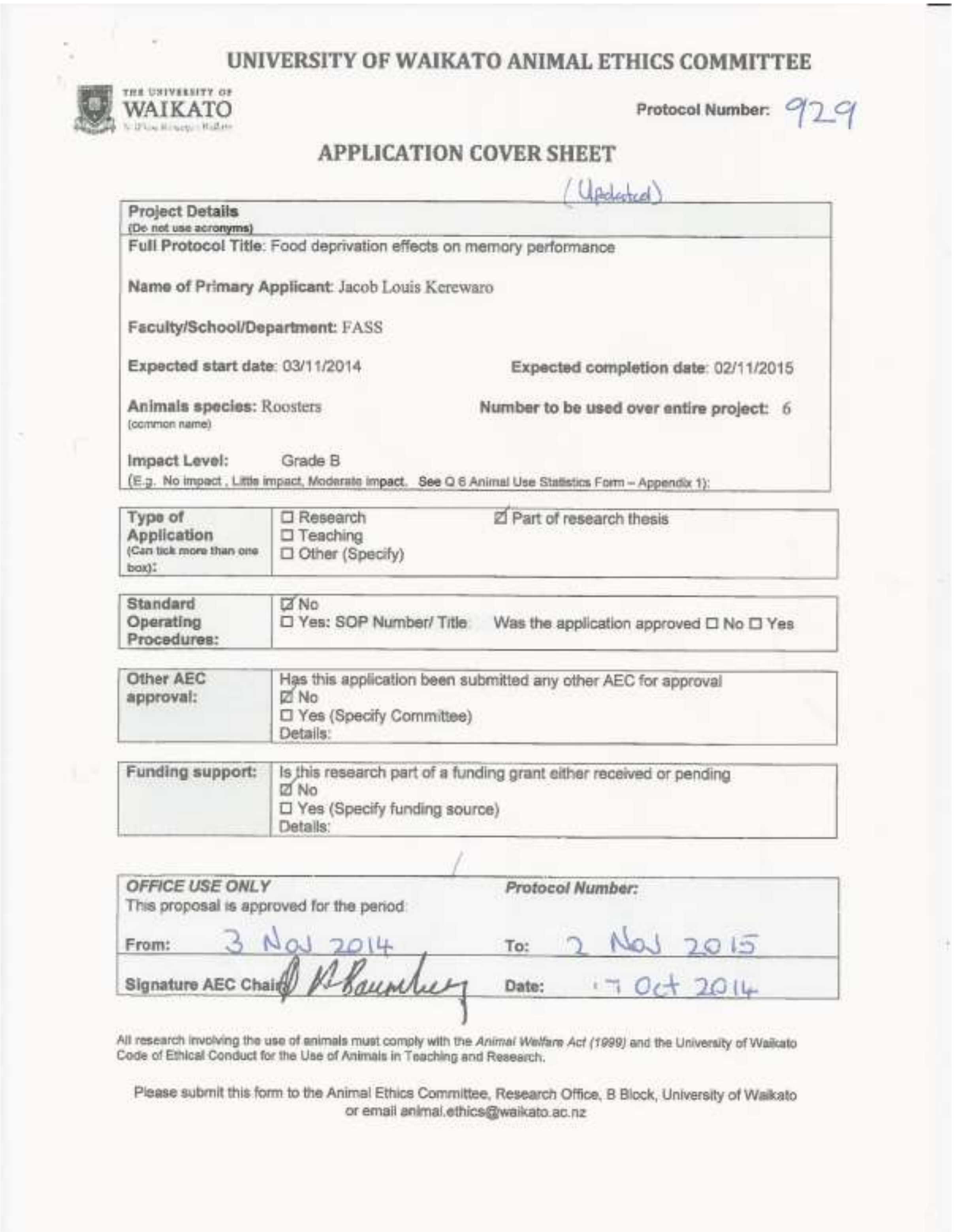
15 Appendix A

The following scanned document and two scanned email are of the ethics approval form and subsequent amendments that was approved by the University of Waikato Animal Ethics Committee. The research was originally approved for one full year. Due to one of the birds dying from a bacterial virus an amendment to the University of Waikato Animal Ethics Committee for a replacement bird was sent through and approved. This is the email received acknowledging the amendment to the research for Protocol 929. An extension of 3 months experimental research to the original 1 year was sought and approved. This is the approval email.



UNIVERSITY OF WAIKATO ANIMAL ETHICS COMMITTEE

THE UNIVERSITY OF
WAIKATO

Protocol Number: 929

APPLICATION COVER SHEET

(Updated)

Project Details (De not use acronyms)	
Full Protocol Title: Food deprivation effects on memory performance	
Name of Primary Applicant: Jacob Louis Kerewaro	
Faculty/School/Department: FASS	
Expected start date: 03/11/2014	**Expected completion date**: 02/11/2015
Animals species: Roosters (common name)	**Number to be used over entire project:** 6
Impact Level: Grade B (E.g. No impact , Little impact, Moderate impact. **See Q 6 Animal Use Statistics Form – Appendix 1**):	

Type of Application (Can tick more than one box):	☐ Research ☐ Teaching ☐ Other (Specify)	☑ Part of research thesis

Standard Operating Procedures:	☑ No ☐ Yes: SOP Number/ Title	Was the application approved ☐ No ☐ Yes

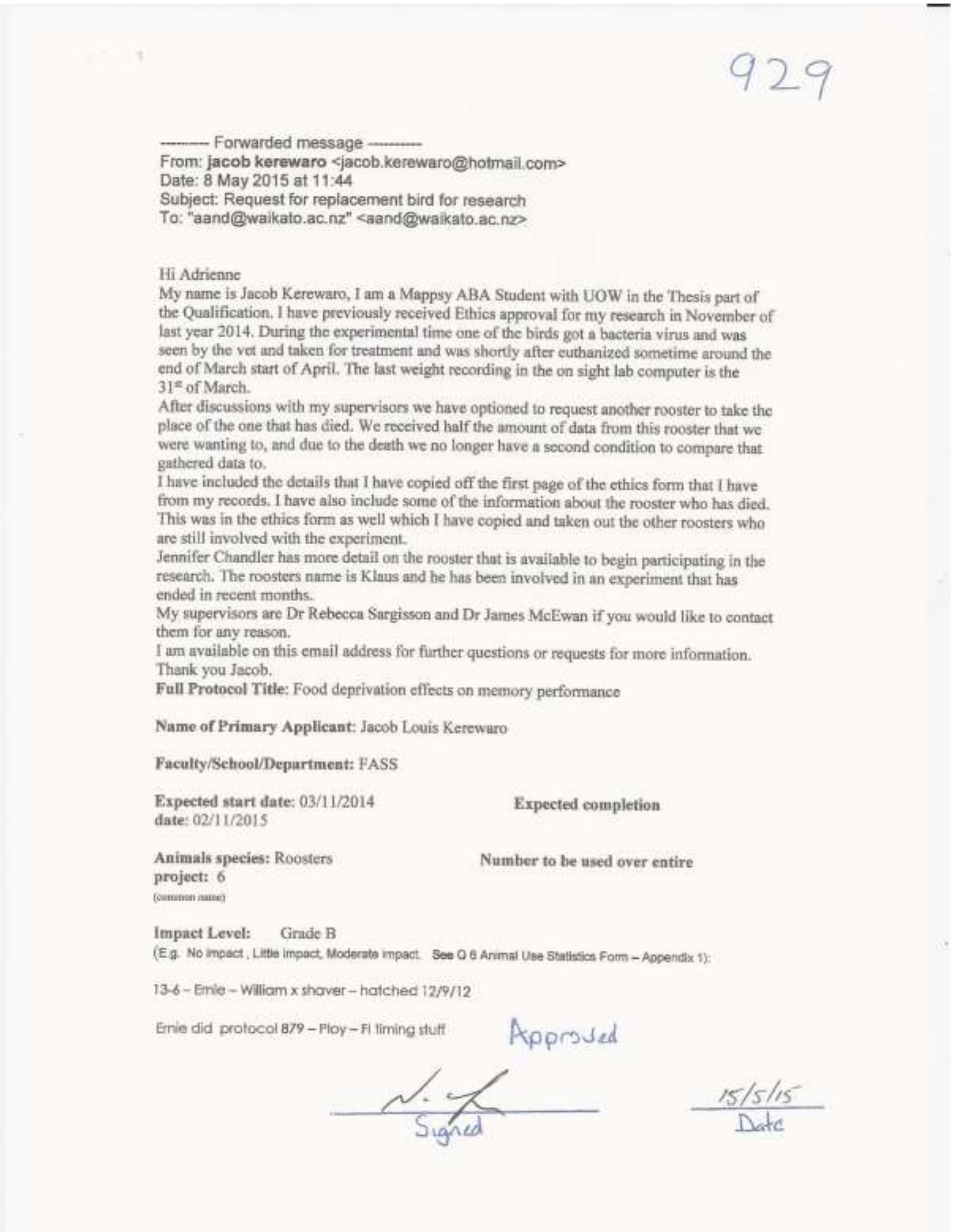
Other AEC approval:	Has this application been submitted any other AEC for approval ☑ No ☐ Yes (Specify Committee) Details:

Funding support:	Is this research part of a funding grant either received or pending ☑ No ☐ Yes (Specify funding source) Details:

OFFICE USE ONLY This proposal is approved for the period:	***Protocol Number:***
From: 3 Nov 2014	**To:** 2 Nov 2015
Signature AEC Chair:	**Date:** 17 Oct 2014

All research involving the use of animals must comply with the *Animal Welfare Act (1999)* and the University of Waikato Code of Ethical Conduct for the Use of Animals in Teaching and Research.

Please submit this form to the Animal Ethics Committee, Research Office, B Block, University of Waikato or email animal.ethics@waikato.ac.nz



929

---------- Forwarded message ----------
From: **jacob kerewaro** <jacob.kerewaro@hotmail.com>
Date: 8 May 2015 at 11:44
Subject: Request for replacement bird for research
To: "aand@waikato.ac.nz" <aand@waikato.ac.nz>

Hi Adrienne
My name is Jacob Kerewaro, I am a Mappsy ABA Student with UOW in the Thesis part of the Qualification. I have previously received Ethics approval for my research in November of last year 2014. During the experimental time one of the birds got a bacteria virus and was seen by the vet and taken for treatment and was shortly after euthanized sometime around the end of March start of April. The last weight recording in the on sight lab computer is the 31st of March.
After discussions with my supervisors we have optioned to request another rooster to take the place of the one that has died. We received half the amount of data from this rooster that we were wanting to, and due to the death we no longer have a second condition to compare that gathered data to.
I have included the details that I have copied off the first page of the ethics form that I have from my records. I have also include some of the information about the rooster who has died. This was in the ethics form as well which I have copied and taken out the other roosters who are still involved with the experiment.
Jennifer Chandler has more detail on the rooster that is available to begin participating in the research. The roosters name is Klaus and he has been involved in an experiment that has ended in recent months.
My supervisors are Dr Rebecca Sargisson and Dr James McEwan if you would like to contact them for any reason.
I am available on this email address for further questions or requests for more information.
Thank you Jacob.
Full Protocol Title: Food deprivation effects on memory performance

Name of Primary Applicant: Jacob Louis Kerewaro

Faculty/School/Department: FASS

Expected start date: 03/11/2014 **Expected completion date**: 02/11/2015

Animals species: Roosters **Number to be used over entire project:** 6
(common name)

Impact Level: Grade B
(E.g. No impact , Little impact, Moderate impact. See Q 6 Animal Use Statistics Form – Appendix 1):

13-6 – Ernie – William x shaver – hatched 12/9/12

Ernie did protocol 879 – Ploy – FI timing stuff

Approved

Signed

15/5/15
Date

11/2/2015 The University of Waikato Mail - Ethics extension application

THE UNIVERSITY OF WAIKATO

Adrienne Anderson <aand@waikato.ac.nz>

Ethics extension application

jacob kerewaro <jacob.kerewaro@hotmail.com>
To: Adrienne Anderson <aand@waikato.ac.nz>

30 October 2015 at 12:35

Hi Adrienne

My name is Jacob Kerewaro, I am a Mappsy ABA Student with UOW in the Thesis part of the Qualification. I have previously received Ethics approval for my research in November of last year 2014, Protocol 929.

I am writing to request an extension of 3 months to my ethics. Some of the birds have not completed both conditions and are short of our set amount of sessions for data collection by approximately 20 sessions. They have been out of the required weight range consistently during the winter months and so have not been running regularly.

My supervisors are Dr Rebecca Sargisson and Dr James McEwan if you would like to contact them for any reason to discuss this further.

I am available on this email address for further questions or requests for more information.

Thank you Jacob.

Extension Approved

From 3 NOV 2015 To: 28 Feb 2016

Chair

3/11/15
Date

https://mail.google.com/mail/u/0/?ui=2&ik=dfb61529b&view=pt&search=inbox&msg=150b5f531b981c49&siml=150b5f531b981c49 1/1

16 Appendix B

The free feeding ad libitum body weights were established during the spring. These graphs were produced to ascertain a stable weight for each individual bird, which would be used to determine 75% or 95% of a normal free-feeding weight (in grams). The figures were produced from weights recorded from 16/09/2014 – 02/10/2014. The final calculations for the birds' means for the experimental conditions were made from the last 5 consecutive days which is shown below.

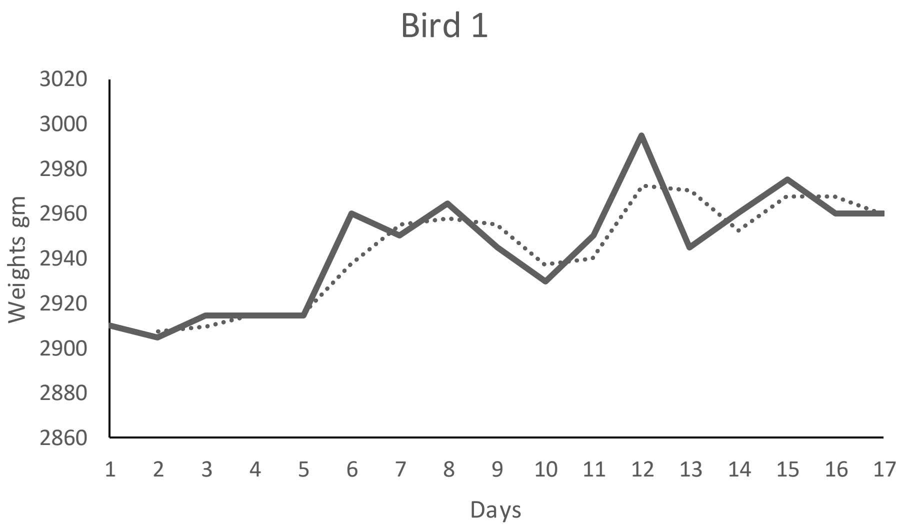


Figure 5. Bird 1 average weight was 2944.411

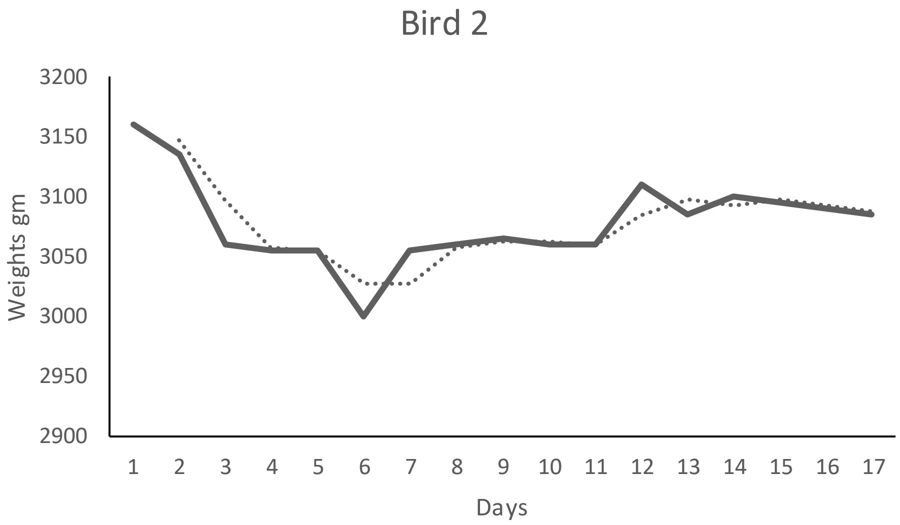


Figure 6. Bird 2 average weight was 3078.235

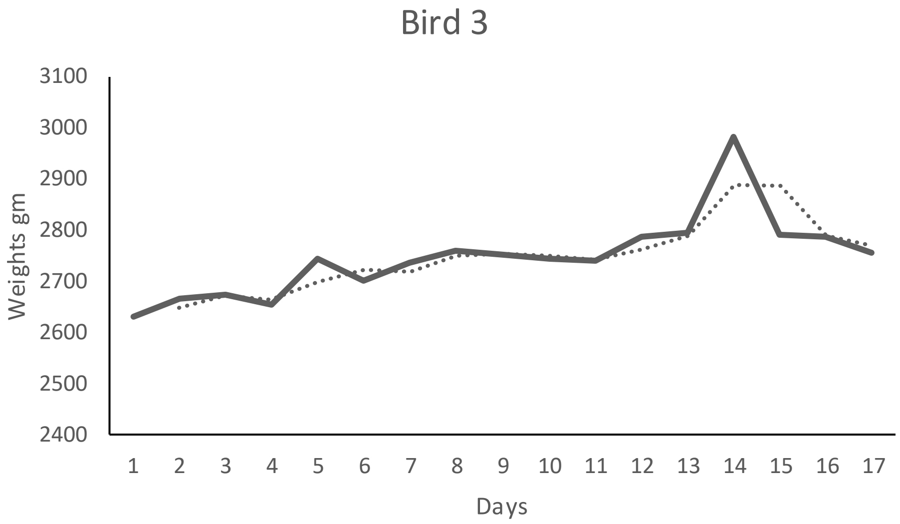


Figure 7. Bird 3 average weight was 2746.470

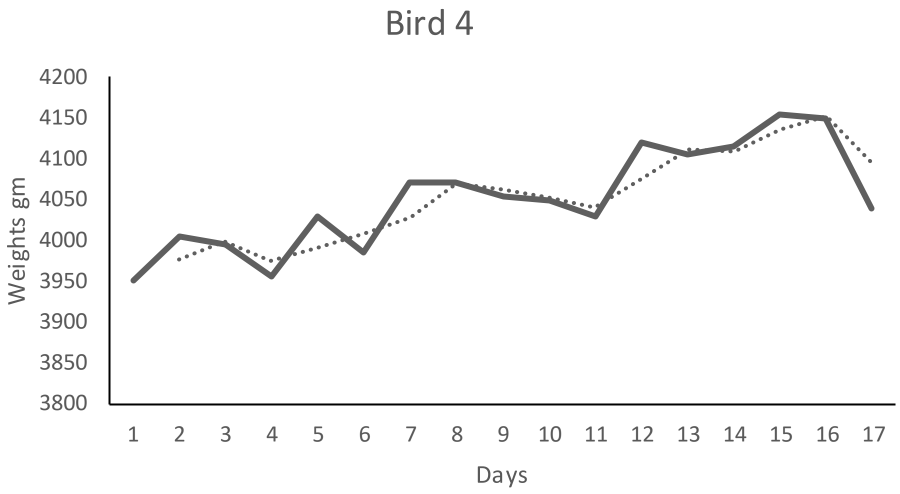


Figure 8. Bird 4 average weight was 4051.764

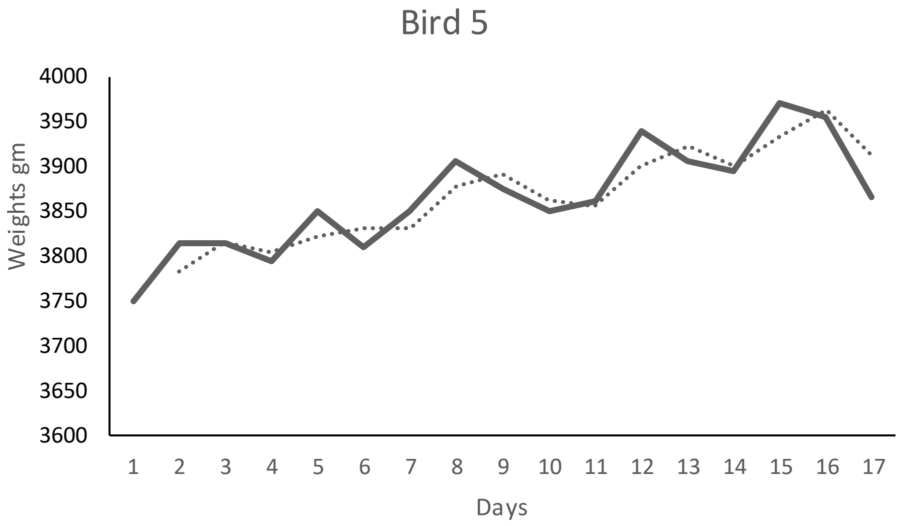


Figure 9. Bird 5 average weight was 3865

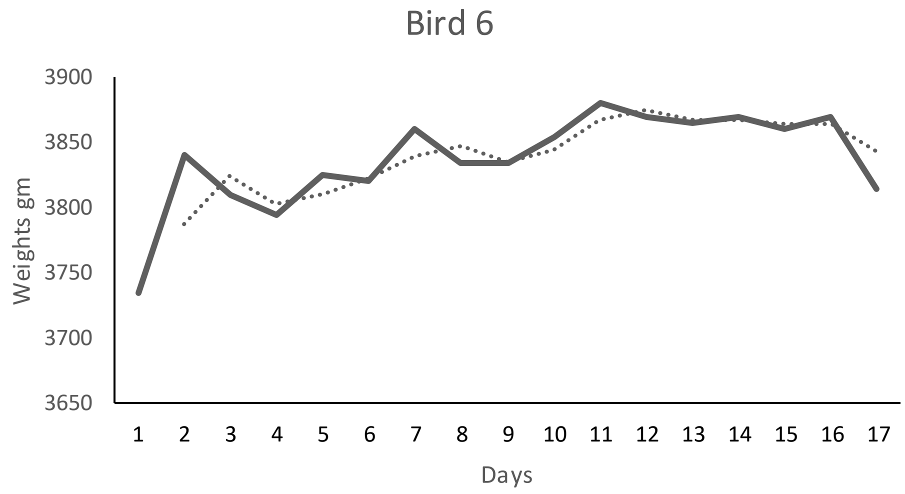


Figure 10. Bird 6 average weight was 3837.647

All six figures have a thick line which is the recorded weight for that day. The thinner line is a moving average calculated by Excel 2013.

Weights percentage calculation.

Participants' average weight to three decimal points / 100 x percentage required.

Final weight rounded to 0 decimal points due to laboratory scale capability.

Variation of 2.5% either side of the calculated weight has been calculated by:

Individual percentage weight / 100 x 2.5.

Individual percent weights were used for each condition and each rooster. This was to have a more accurate calculation of the variation for each individual rooster when in a different condition.

Table 5
Free Feeding Weights and Experimental Condition Percentages

Bird	FF Weight average	75% condition	95% condition	±2.5% at 75% FF weight	±2.5% at 95% FF weight
Bird 1	2944.411	2208	2797	55	69
Bird 2	3078.235	2308	2924	57	73
Bird 3	2746.470	2059	2609	51	65
Bird 4	4051.764	3038	3849	75	96
Bird 5	3865	2898	3671	72	91
Bird 6	3837.647	2878	3645	71	91

The free feeding weights that were established from the last 17 days before beginning the experiment were then reduced to the last 5 days. This was done to provide an accurate weight range. The previous 17 days looked to ascertain whether the bird's weights were stable and not fluctuating at large amounts. These 5 days were then calculated at an original ±1.5% of the target weight, shown below, and then increased to ±2.5% to increase experimental sessions participated in.

Table 6
Average Weights in grams and Percentages during last 5 days of free feeding

Bird	FF Weight in grams	Order of conditions	Minimum weight	Maximum weight	±1.5%
Bird 1	2982	95, 75	2788	2877	44.73
Bird 2	3140	75, 95	2277	2432	77.10
Bird 3	2863	95, 75	2677	2762	42.94
Bird 4	4141	75, 95	3043	3168	62.11
Bird 5	3959	95, 75	3701	3802	59.38
Bird 6	3819	75, 95	2806	2921	57.28

Weight condition target weights ±1.5 (Note this was extended to ±2.5% as most birds were rarely inside the required weight range, which caused few birds to participate in experimental sessions and/or participate regularly).