Effects of Food Deprivation on Memory Performance.

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Abstract

The effects of two different states of food deprivation for 6 roosters was measured with a delayed matching-to-sample (DMTS) procedure. The DMTS procedure was used to measure short term memory. The behaviour of roosters held within 2.5% of a spring established that ad libitum free feeding body weight of 75% and 95% were the two conditions. Previous research has noted that pigeon weights fluctuate over a calendar year (Sargisson, Mclean, Brown, and White, 2007). Weight recordings were heavier during the winter and lighter during the summer months. This may affect the performance of experimental animals held at established weights for a long time. This research attempted to assess whether a lower body weight may produce more correct responses in a DMTS procedure. The current data collected has shown three roosters to perform better at a higher body weight.

Keywords: Food Deprivation, Memory Performance, Weight

Introduction

This research was a quantitative study of non-human animals of the avian species with two different food deprivation levels. It is suggested that weight variations could have an effect on motivation to perform (Sargisson et al., 2007). Sargisson et al. (2007) posit that seasonal fluctuations of weight may have an effect on the accuracy of performance with a memory task by pigeons. The performance accuracy of memory is measured by the correct response after a temporal distance between a stimulus and the recall of this stimulus. The previous research of Sargisson et al (2007) found that the pigeons — when at a higher level of deprivation — performed a memory task with more accuracy.

Generally accepted procedures are to maintain research animals at a lower percentage of what may be considered to be a normal weight for that animal naturally (Makowiecki Hammond, & Rodger, 2012). This is a standard operant based procedure to motivate the animal to perform the task required (Skinner, 1953). When depriving an animal of food we are manipulating the environment to produce a behaviour. This is upheld by operant experimenters (Makowiecki et al., 2012; Sargisson et al., 2007; Skinner, 1953).

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 occurring since at least the 1950s (Bare,1958; Bokkers, Koene, Rodenburg, Zimmerman and Spruijt, 2004).

Makowiecki et al. (2012) looked at the possibility of confounding ethical weight restrictions when experimenting with nonhuman animals and food deprivation. The weight restrictions were 80% and 90% of ad libitum body weight. A visual discrimination task in a Y maze, which led to a positive reinforcement from one visual stimulus and was then switched to the opposite visual stimulus, tested the behavioural learning and reversal of 2 different genotype mice which had no difference between these two types in learning and reversal. The

80% group performed the task more accurately than the 90% group. They were able to learn and reverse the task sooner than the 90% group. The authors suggest that overfeeding could be just as dangerous as underfeeding due to the health complications of being overweight. This may also be disadvantageous to learning behaviour. The 95% ad libitum body weight may not elicit performance of the DMTS task either for lack of motivation or the ability to learn the DMTS task and perform it accurately.

Seasonal change and the effect it may have on weight is an important variable to take note of during experimental conditions. The seasonal time of the year may have an effect on the weight of an animal. It is important to acknowledge that results may be affected by seasonal changes if those changes affect performance. Short term weight dependent experiments may need to consider the season to accurately determine the results.

Sargisson et al. (2007) used two groups of pigeons. Firstly, a group were weighed during three seasonal calendar years whilst being free fed. The second group performed a DMTS task over a calendar year at 85% of a summertime ad libitum free feeding body weight. Summer ad libitum body weights would suggest that during the winter season the pigeons are at a naturally higher deprivation level, even though the 85% of free feeding body weight does not change during the experiment. When the pigeons were motivated by a suggested higher state of deprivation, the performance accuracy on the DMTS task was seen to increase (Sargisson, et al., 2007).

The delayed matching-to-sample (DMTS) experiment was designed by Blough (1959) in the late 1950s. He used an operant chamber with three keys side-by-side, which could be illuminated. After presentation of a sample stimulus, such as a coloured light on the centre key, there was a delay. This was to provide a temporal distance between exposure to the stimulus and the opportunity to recall and respond for reinforcement. After the delay, the keys on either side of the centre key would be illuminated. One side key would match the sample presented previously in the centre key, while one side key would not match the sample presented in the centre key. The pigeon would then be required to peck one of the two illuminated keys, and would be given reinforcement for correctly matching the same coloured light presented before the delay with one of the two coloured lights presented after the delay. Food would be given when the pigeon pecked the key that corresponded to the stimulus presented on the middle key before the delay (Blough, 1959). As temporal distance increased between stimulus presentation and the opportunity to respond on a key for reinforcement in this DMTS experiment, the percentage of correct responses decreased. Blough (1959) observed that there was a lower percentage of correct responses when the delay was longer. 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) developed the delay procedure to observe the pigeon's behaviour between stimulus presentation and the opportunity to respond. The matching of a sample stimulus and comparison stimuli after a delay became useful as a memory test for researchers (Alsop & Jones, 2008; Brown & White, 2005; Calder & White, 2014; Goto & Watanabe, 2009; Sargisson et al., 2007).

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 can illustrate, by way of a fitted curve, the decay of memory over different lengths of time (Blough, 1959; Brown & White, 2005). From the curve, both the rate of forgetting over delays (slope) and initial discriminability in the absence of a delay (intercept) can be derived.

Hypothesis

I hypothesise that forgetting functions resulting from the birds' performance on the DMTS task will be shallower when the subjects are in a higher state of deprivation, showing better remembering at longer time delays. I hypothesise the opposite at the lower states of deprivation. This research may suggest that weight might act as a confounding variable in experiments that use free-feeding weights from differing seasons in a calendar year; either during the different conditions in the same research or when replicating other research.

Method

Subjects

The subjects were six roosters — four experimentally experienced roosters and two naïve roosters — numbered 1 to 6. 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.

Bird 5 died before completing the experiment and was replaced by another rooster named Bird 7, this replacement bird did not complete both conditions within the experiment time frame and so neither of the two birds (5 and 7) were included in the final data analysis.

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 condition, through increasing or decreasing supplementary food, dependent on the amount of reinforcement they received. Birds 1, 3, and 5 started in Condition 1 (95%) and Birds 2, 4, and 6 started in Condition 2 (75%). Bird 7, which replaced Bird 5, started in Condition 2. 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 seven days a week, and were run at about the same time each day. At the end of an experimental session, the roosters were returned to their home cages.

Apparatus

The apparatus was an operant chamber approximately 1190mm wide, 750mm high and 530mm deep. 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 by 1-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 is available. The chamber was controlled by a Med-PC computer programme.

Procedure

Following training (see below), the birds started in one of the two conditions: 1) a DMTS task was performed by the birds at a low level of food deprivation (95% ± 2.5% of free feeding body weight); and 2) the same DMTS task was performed at a high level of food deprivation (75% ±2.5% of their free feeding body weight). All of the birds were to participate in both conditions, with three birds participating in condition 1 first and three birds participating in condition 2 first. The birds were then changed between the conditions when they had completed 50-55 sessions in the previous condition.

Each bird was to complete the training DMTS task at zero seconds delay, and was to achieve 80% or more correct 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 consistently 80% correct at 0-s, delay it then began the experiment with the full set of delays of -0.2, -1, -3, -6, and -12 seconds.

The DMTS task the birds were then put on was consistent with the research run by Sargisson et al. (2007). The same programme with the same delays, reinforcement allocations, time lengths between trials, reinforcement, and maximum session times were all identical and from the original programme used in Sargisson et al., (2007). The experimental session began with 10 pre-trials that were not included in subsequent data analysis. The procedure is as described above. As in the training, one side key was lit red and the other green in a random order. When the bird pecked the key that was the same colour as that presented on the centre key prior to the delay, the bird received 3-s access to wheat from the food hopper. When the bird pecked the key that did not match the colour that was previously presented, the chamber went into a blackout for 2-s. There was an inter-trial interval of 15-s before another trial began. The chamber was in a blackout during the inter-trial interval. There were a total of 81 trials per session or 40 minutes, whichever occurred first. The delay times were 0.2-, 1-, 3-, 6- and 12-s. When the bird had completed 50-55 experimental sessions, they commenced the opposite condition.

It was assumed that there may be some learned behaviour. This could concede that when participating in the next condition, the response rate and trial number completed per session may be higher than the earlier sessions of the original condition. The data analysed was taken from the sessions that produced approximately the last 400 trials of the 50-55 session requirements in each condition. When all trails are completed, the number of sessions required to have 400 trials is 5. This was considered to be a snap shot of regular behaviour. The last ten sessions of the 50-55 sessions was also analysed to see if there was any difference, as some birds were not completing all trials or were scattered in the number of trials completed.

The Microsoft Excel 2013 spreadsheet program was used to transform the raw data to percent correct for the delays, the number of trials, the number of correct red and correct green, and the number of errors red and errors green. This program was also used to calculate the Log d from approximately the last 400 trials of the finished condition.

The logarithmic function of Log d to convert data in this research is as follows.

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

Where c= correct and e=error

red= colour of stimulus

green= colour of stimulus

Sigma Plot 12.5 was used to plot the exponential decay, single, 2 parameter curve and provide the calculated data report on the R^2, *a* (intercept), *b* (slope). The Log d data was the plot points for this graph and report. The exponential decay curve to fit provides the forgetting function for each condition.

Results

Early on in the experimental process it was shown by Bird 1 that 95% of FF BW was not enough of a motivating operation to invoke the behaviour required to collect data. This bird was naïve to an experimental chamber, and after successive attempts to hand shape, reshape, and train the required behaviour, this bird would not perform. It was decided to change Bird 1 into the 75% FF BW condition. It was decided that he may not be motivated by hunger when so close to a FF BW. When Bird 1 was at the target weight, he was trained on a VR 3 schedule and then placed on the full delays, at which point he started to perform and began to regularly complete the set number of trials within the 40 minute session. Bird 1 completed the 50 sessions at the 75% condition, but did not participate any further due to time constraints. Because there is no comparative data from both conditions, the results for Bird 1 will not be presented.

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 and then be outside the weight range, which then required a small number of days to come back down in weight. This occurred regularly during the warmer months.

As the weather changed from warmer to cooler, the participants would regularly be over the 2.5% variance of their target weight. This contributed to irregular running of the experimental sessions on consecutive days.

When all the birds had changed from their starting condition to the next condition, the trial numbers per session started to become stable. This may show that the behaviour had been learned and was established. The effect of the independent variable of weight may be seen, as the performing of the birds would be reliant on the motivating operation of hunger. The forgetting function slope may show between the birds' data that when the behaviour is established the state of food deprivation can affect the behaviour.

Figure 1 shows the analysis of the data for approximately the last 400 trials of both conditions (right side of figure 1). The results for Bird 2 show an increase in performance and accuracy when in the heavier 95% condition. The difference between all of the delay data points in figure 1 shows that when less deprived Bird 2 will perform the task more accurately across all of the delays. The slopes are similar indicating that the increase in accuracy from the 75% condition to the 95% condition was similar for all of the delays.

The data for Bird 3 in figure 1 shows a crossover of performance with the slope at around 6 seconds. The intercept is higher for the 75% condition as shown in Table 1. Table 1 shows the slope of the performance of Bird 3 to be different between the 95% condition and the 75% condition. Table 1 shows the 75% condition to be 0.27 and the 95% condition is 0.11. This shows that the slope is greater for the 75% condition and shallower for the 95% condition. This suggests that the performance for Bird 3 when at a least deprived state is more stable.

Figure 1 shows Bird 4 has a better performance and accuracy when less deprived. The intercept was higher for the 95% condition as Table 1 shows: the intercept for the 95% condition was 2.06, and the intercept for the 75% condition was 1.44, the higher number indicating a higher accuracy when at the least temporal distance, that being 0 seconds. The difference between the slopes was not large — 0.14 for the 75% condition, and 0.09 for the 95% condition. The smaller number indicating a shallower slope.

As highlighted in Figure 1, Bird 6 had very different results for the slope of approximately the last 400 trials of the two conditions. The 75% condition slope was 0.33 and the 95% condition was 0.06 as shown in Table 1. The performance over all of the delays is performed more accurately by Bird 6 when least deprived. The intercept for both conditions are similar: 1.82 for the 75% condition, and 1.66 for the 95% condition, as shown in Table 1. This shows that at the smallest temporal distance for the two deprivation levels, there is not much separating the performance of Bird 6. The most deprived condition is also the condition with the higher intercept. This suggests that Bird 6 is more accurate when more deprived, yet only for the shorter delay.

Figure 1 also shows the mean across all birds for approximately the last 400 sessions. It shows a similar intercept and slope. The mean for intercept of the 75% condition is 1.72, and 1.61 for the 95% condition as shown in Table 1. Table 1 shows for the 75% condition the slope is 0.02 and for the 95% condition it is 0.06. All data points for the mean of both conditions with error bars gradually become separated as the delay increases. The initial accuracy at 0 seconds delay (the intercept) is similar in both conditions.

The results for approximately the last 400 trials of the birds that completed both conditions show that the behaviour of pecking a key, to match coloured lights after a temporal distance, is more accurate when least deprived.

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 400 Trials Approximately.

Bird	**Condition**	**R^2**	***A***	***b***
2	75%	0.77	1.24	0.13
2	95%	0.85	1.56	0.08
3	75%	0.89	2.23	0.27
3	95%	0.96	1.10	0.11
4	75%	0.84	1.44	0.14
4	95%	0.82	2.06	0.09
6	75%	0.72	1.82	0.33
6	95%	0.53	1.66	0.06
Mean	75%	0.71	1.72	0.02
Mean	95%	0.94	1.61	0.06

Figure 1 also shows the analysis of the data of the last ten sessions of both conditions (left side of Figure 1). Both analyses present a similar result. There is some variations with the intercept and slope for all of the birds presented

The results for Bird 2 from the last ten sessions are similar to the last 400 trials. The slope for the 95% condition is the same at 0.08. The intercept is lower for the 75% condition at 1.13, as shown in Table 2. The intercept for the 95% condition is higher at 1.79, as shown in Table 2. The 95% condition is still the condition which has the better overall performance and accuracy over all delays.

Table 2 shows for Bird 3 that the 75% condition has a higher intercept at 2.32 than the 95% condition of 1.32. The slope for the75% condition is 0.26, making it steeper than the 95% condition which has a slope of 0.13 as shown in Table 2.

The intercept for Bird 4 in the 95% condition is lower for the last ten sessions — 1.83 as shown in Table 2 — than for approximately the last 400 trials, which is 2.06 as shown in Table 1. The slope for the 75% condition is 0.15, as shown in Table 2, which is only slightly steeper than that of approximately the last 400 trials, which is 0.14 as shown in Table 1. The slope for the 95% condition with both analyses was the same at 0.09, as shown in Tables 1 and 2.

The intercepts for Bird 6 from the last ten sessions were 2.08 for the 75% condition, and 1.88 for the 95% condition, as shown in Table 2. The slope for the 95% condition is slightly shallower when analysed with the last ten sessions 0.11, as shown in Table 2. The slope for approximately the last 400 trials in the 95% condition was 0.06, as shown in Table 1. The mean across all of these birds for the last ten sessions, shown in Figure 1, again present a similar result to the mean of approximately the last 400 trials. The intercept for the 75% condition, 1.75, is higher than the 95% condition of 1.65, as shown in Table 2. The slopes of both conditions for the last ten sessions shown in Table 2 show the 75% condition slope to be shallower at 0.03 than the 95% condition of 0.07.

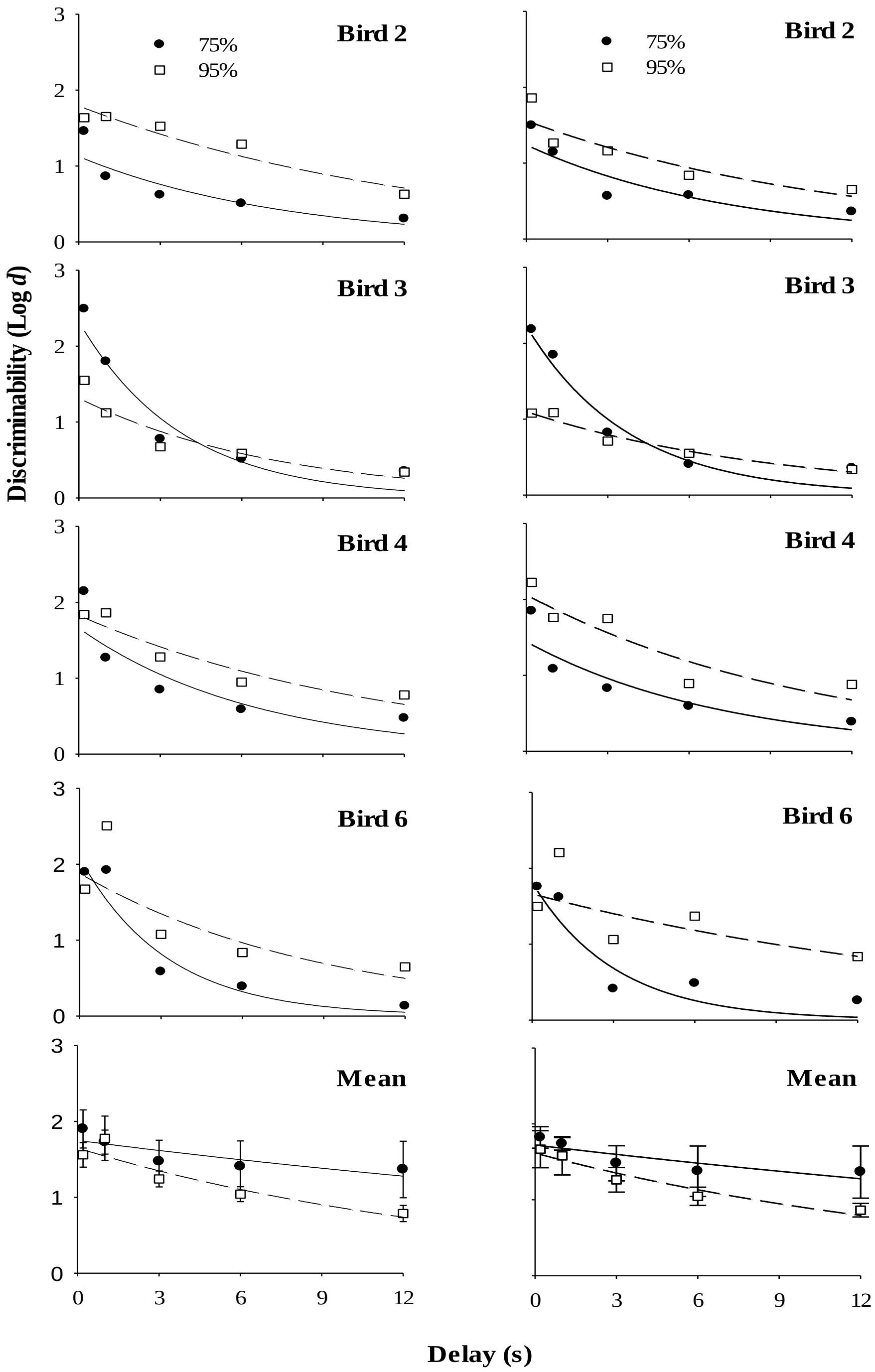
Table 2

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 Ten Sessions.

Bird	**Condition**	**R^2**	***a***	***b***
2	75%	0.82	1.13	0.13
2	95%	0.94	1.79	0.08
3	75%	0.87	2.32	0.26
3	95%	0.87	1.32	0.13
4	75%	0.77	1.66	0.15
4	95%	0.90	1.83	0.09
6	75%	0.92	2.08	0.31
6	95%	0.70	1.88	0.11
Mean	75%	0.69	1.75	0.03
Mean	95%	0.90	1.65	0.07

Figure 1

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 ten 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.



Discussion

Birds 2, 4, and 6 all performed better when in the less deprived condition. This is counter to the hypothesis. The suggestion for this — when looking at the procedure, and these birds — is the order in which they participated in the two conditions. All three birds started in the high deprived condition before moving to the least deprived condition. This may have inadvertently caused a learning bias. Birds 4 and 6 repeated the high deprived condition, and the results have suggested that this may have occurred. Another suggestion was that the birds were in the least deprived condition during the winter months. As the hypothesis argues, in winter the birds may be naturally heavier. In this case, it may have caused them to be more motivated to perform due to the season. If the hypothesis were accurate, the deprivation level of 95% FF BW during the winter may have been greater naturally. It was common for those birds in the 75% deprived condition to be overweight during the winter months that the experiment was conducted.

Bird 3 showed a similar performance when comparing the two conditions and the two different analyses of the data. There were some problems with Bird 3 and the regular running of Bird 3 when in the most deprived condition (75% FF BW). Bird 3 would regularly be over the weight range, and take a week or two to be within the target. With inconsistent running, the comparison of the data between subjects was more difficult to suggest learned behaviour by way of regular repetition. With the data analysis Bird 3 providing a similar result, there is not much to indicate why this bird had differing results to the other birds. The performance within subject is stable yet unexplained. Bird 3 was regularly not completing all of the trials during a single session. This may have had an effect on the data if the data is coming from the same delays rather than an even spread of all of the delays.

Limitations

The order in which Birds 2, 4, and 6 completed the conditions has suggested that there may be a learning bias. This means being unable to compare the data without acknowledging that confound. If Birds 2, 4, and 6 had been able to perform the task better when at the less food deprived state because the behaviour had been practiced and learned, this may suggest that the condition that they participated in second would ideally be a better performance.

The results of Birds 2, 4, and 6 show that their performance was better when they changed between the two conditions. The condition that they completed second was the less deprived condition, 95% of their FF BW. It is during this condition that they had a higher accuracy when both conditions performance was compared.

Birds 1, 3, and 5 all had disruptions during the experimental phase. Bird 1 would not perform when in a low deprived state. Bird 1 was changed to a higher deprived state which he did complete, which could not provide comparable data.

Bird 3 could not have a maintained weight to successfully complete the 95% condition. Bird 3 fell short of the 50-55 session's required for the 95% condition. Bird 3's data analysis was from the last trials and sessions of the 95% condition that had been completed. Bird 3 also had irregular running days due to being outside of the weight range. When reviewing some of the data, it could be seen that the performance may improve when regularly running in the experiment. When there were days between running, the completion of the session would decrease. Bird 3 did not always complete the full number of trials per session. This may show an inaccuracy in the data if the delays that are performed are regularly long or regularly short. A high accuracy may be seen when analysing the number of trials; however, if those trials are an inaccurate spread of the possible 81 trials for the session time, the results may be affected due to an imbalance in the data analysed. The same could be said for a low accuracy of performance. If the data from Bird 3 is mostly long delays form incomplete sessions, which are regularly incorrect, the data will reflect an inaccuracy of memory performance.

Bird 5 completed one condition before dying, thereby not having any comparison data, and so was not included within the results. Bird 7 did not finish either condition before the end of the experimental phase. This bird's data was also not included as there was no comparison data or stable performance length to make a suitable analysis. With these birds and the order that they participated, the conditions may have given data which could have balanced the impression that the birds improved their performance over successive repetition.

Conclusion

Given the different results from the Sargisson et al. (2007) paper, it is difficult to determine whether the deprivation level has a definitive effect which can be stably predicted. The different species, environment, and weight conditions have added to the discussion. There were some clear differences between this thesis research and the previous research. What can be said is that there are seasonal variables which could have influenced the results. During the summer months it was found to be 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 do indicate that there may have been some learning of the task, as well as a ceiling effect of not being able to achieve any better. This situation was unavoidable by way of the birds needing to complete both conditions in a consecutive order.

This research has provided some insights on how much deprivation is required for motivation to perform a behaviour. It also suggests that the seasonal weather has impacted the process of gathering the data. The birds that participated were not exactly the same in the order, the performance, or the consistency of the behaviour when weight factors were taken into account. Manipulating the weights during different seasons created difficulties that similarly fit with the hypothesis of weather being an influence. The DMTS task itself was the same during the procedure of both conditions. The data from this task suggests that once the behaviour is acquired, the memory is relatively stable in this instance.

This research has explained the process by which a DMTS task has been used to test memory performance and accuracy whilst in two different states of deprivation. A higher state of deprivation was considered to create a higher level of accuracy. Seasonal change throughout a calendar year is suggested to have an effect on weight, as it fluctuates between weather cycles. The results have suggested that learning the behaviour has conflicted with previous research. However, conditions throughout the calendar year suggest that there is an impact of weight and seasonal change. This may not be entirely performance relevant, and may only affect an attempt to maintain a strict weight range throughout a full year or more.

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