AUTOMATED ENRICHMENT FOR ENHANCING ANIMAL AND RESEARCHER WELFARE

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Automated Enrichment Use in Psittacines. (May 2015)

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Captive animals lead lives that are extremely limited in activity compared to conspecifics in the wild. To compensate for the lack of stimulation compared to the wild, enrichment supplementation is standard practice at the Schubot Center at Texas A&M University. Enhancing animal enrichment is becoming an increasingly important topic among many in the zoological and veterinary communities as an escalating amount of animals are kept in captivity. Static toys are often used in enrichment, but often become monotonous, are destroyed, or do not provide adequate stimulation for the animal to thrive. In order to provide a more sustainable form of animal enrichment, a digital enrichment device was developed and tested using two Quaker Parakeets, *Myiopsitta monachus*. This digital enrichment, or digital toy, was utilized as a part of the birds' normal care to offer a game that could not be destroyed by the animal, while also providing fluctuating mental stimulation. This enrichment consisted of a game that automatically recorded information about the bird's interactions via a tablet and provided insight into each birds' learning rate. The individuals were compared using chi square analysis, comparison of means, and linear regression to detect the variability of response to enrichment. Both birds interacted with the device and were successful in playing the game on the computer screen, but during different times in the trials. The male was more active (measured as vocalizations per

second) overall, but took more sessions to be at peak activity, while the female started at a slightly higher interaction rate but slightly decreased over time. The male also began having high accuracy (measured as hits/ total responses), but declined over trials, while the female increased her accuracy. Though there must be further studies conducted on this technology to provide a stronger base, this design shows feasibility of digital toys for sustainable enrichment for animals in captivity, and using digital enrichment toys as a method for data collection within animal research.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Animals are kept in captivity for a wide variety of reasons, including research, rehabilitation, and education. However, animal species are not evolved to live in captivity, and even the most highly domesticated species can suffer from lack of mental stimulation in captivity. Non-domesticated species may suffer to an even higher degree due to a loss of their self-sufficient lifestyles. To create environments that are physically, socially, and cognitively appropriate, caging is improved by additions called "enrichment." Enrichment is defined by the Behavior Scientific Advisory Group as "a dynamic process for enhancing animal environments within the context of the animals' behavioral biology and natural history" (Behavior Scientific Advisory Group, n.d.). Animal enrichment is a young field that has substantial room for growth and development (Shepherdson & Mellen, 1998). The USDA has proposed "task oriented feeding" as a method for environmental enrichment (Reinhardt, 1994). It has been known since 1963 that rats prefer to work for their food even when identical food is freely available (Jensen, 1963). The preference to work for food is called "contrafreeloading," and has been shown across clades, including pigeons and primates (Reinhardt, 1994; Neuringer, 1969; Singh, 1970).

Animals will seek out a challenging task that, according to Reinhardt, will be "serving as its own reward" (Riendhardt, 1994). Completing tasks for food items is a natural expression of behavior for animals. Animal behavior has also been studied using a device called a skinner box. A skinner box is a tool used for automatically training behaviors within an animal popularized by scientist B.F. Skinner. This tool is a box that automatically provides food rewards to increase the frequency of an accidental behavior. As the animal seeks to replicate the scenario that provided the reward, the accidental behavior becomes an intentional behavior performed for reward (Skinner, 1932). It is possible for this form of accidental training to be implemented in a manner that is mutually beneficial for the animal and their human counterparts.

The issue with enrichment is that attempts often end up being costly, short- lived, ineffective, or a combination of the three because budgets are often tight and enrichment requires both manpower and consumable supplies. Because animals have adaptive learning systems, animals may outpace the challenge of enrichment that is provided, leading to animal caretakers who suffer “enrichment burnout” where they do not have options to meet the needs of the animals (personal communication with Constance Woodman regarding being a zookeeper). Rather than this exhausting form of upkeep, a process of easily sustainable enrichment could be used to simplify lives of captive animals along with their caretakers.

The most important aspect of enrichment is the benefit to the life of the animal. Often, animals grow bored when not provided with adequate novel stimuli, or worse, lack the necessary stimulation needed for normal development and neurogenesis. This can lead to negative or destructive behavior. For birds, this can provoke reactions such as biting, screaming, and feather-plucking or other forms of self- mutilation (Hoek, 1998). These pathological behaviors are likely signs of abnormal development and are probably confounding factors for research. If an engaging, appropriately challenging, exciting activity can be provided, it would keep a bird actively engaged each time they wish to play. A potential key to making the activity fun and engaging is the idea of flow, studied by Jenova Chen (Chen, 2007). The concept of flow is characterized by an optimum ratio of the challenge of the game compared to the ability of the player. If the challenge is much more than the player's abilities allow, it can lead to anxiety associated with frustration. Likewise, if abilities of the player are much greater than the challenge, the player can easily become bored. Providing a steadily increasing difficulty level which matches pace creates an environment that is productive and exciting, using one device.

If a single apparatus could provide multiple facets of engagement and species appropriate cognitive challenges, it would reduce the need to purchase multiple short-lived toys. For example, a single bird toy may cost $100, but be quickly consumed (Google Shopping search for "macaw toy", 11.20.14). To create increasing levels of complexity, buying multiple puzzle feeders to keep pace with a parrot's learning would be an expensive process. An automated enrichment system is able to provide a variety of programs within one device. With this sort of versatility, the consumer would only need to be concerned with physical destruction of the device. A toy with low wear and tear that is mentally stimulating would lead to a new, sustainable form of animal enrichment.

A fair amount of animal behavior research collects data through direct observation. This sort of watching may cause a modification of behavior (Landsberger, 1958). Data collection by human observation may also be tedious, monotonous, and prone to error. Because of these issues with human data collection, other methods have been put in place, namely automatic data collection. Automatic data collection has been successful for detecting behaviors in wild animals (Hensler, Klugman, & Fuller, 1986). This type of monitoring combined with enrichment makes it possible to collect cognitive data with reliability and ease. What time is saved by automatic data collection could assist to give more time for data- collectors, largely undergraduate students, to have meaningful experiences in research. For undergraduates and professors alike, a large interest involving a student in research is giving them the ability to understand the nature of scientific knowledge (Hunter, Laursen, & Seymour, 2007) instead of spending hours in observation.

The purpose of this experiment is to investigate the use of automated enrichment for mental stimulation and simultaneous automated data collection in a captive colony of Quaker Parakeets, *Myiopsitta monachus*. A modified, humane Skinner box was provided to two Quaker Parakeets who were presented with the opportunity to interact with and receive appropriate food rewards. A portable smart device mounted on the outside of a cage provided a mentally stimulating activity with steadily increasing difficulty level, while simultaneously collecting the data on the bird's use. A simple belt feeder plugged into the device's audio port delivered the enrichment rewards. This mentally stimulating toy with low wear and tear provides a new, sustainable form of enrichment that can last. This system is a user- friendly, animal- friendly form of enrichment that could be used to improve the lives of captive animals everywhere.

CHAPTER II

METHODOLOGY

Study Design

Digital enrichment was provided to two hand raised Quaker parrots (*Myiopsitta monachus*). When the birds were not being given the supplemental enrichment, they were housed in the same enclosure which was 48x24x48 inches. The enrichment was provided to one bird at a time in their normal enclosure, while the other was moved into a nearby identical cage. The birds were interacted with regularly before they were moved into the enrichment area to reduce the stress of transportation. They were trained to enter carriers using operant conditioning, using a small flashlight as a bridge. This flash of light mimicked the screen flash portrayed by the game when a correct response was received.

Design of System Technology

The system is composed of a mounted tablet computer, a circuit, and a belt feeder. The system is pictured in Figure 2.1 (front view) and Figure 2.2 (top view with labels). The price chart for the components of the system is also provided in Figure 2.3. Objects listed as “in house” were created through custom design using the SolidWorks 3D design software and a Stratasys mojo 3D printer. This allowed us to quickly and inexpensively create the system. The only component that was not added to Figure 2.3 is the monitor. We suggest recycling devices that you already own (i.e. smart phone or tablets) for this purpose, but if you wish to buy a tablet especially for this product NextBook 7 inch is the recommended device, which is priced at $60 at Walmart. In this study, a SurfacePro 3 was used.

Figure 2.1- Front View

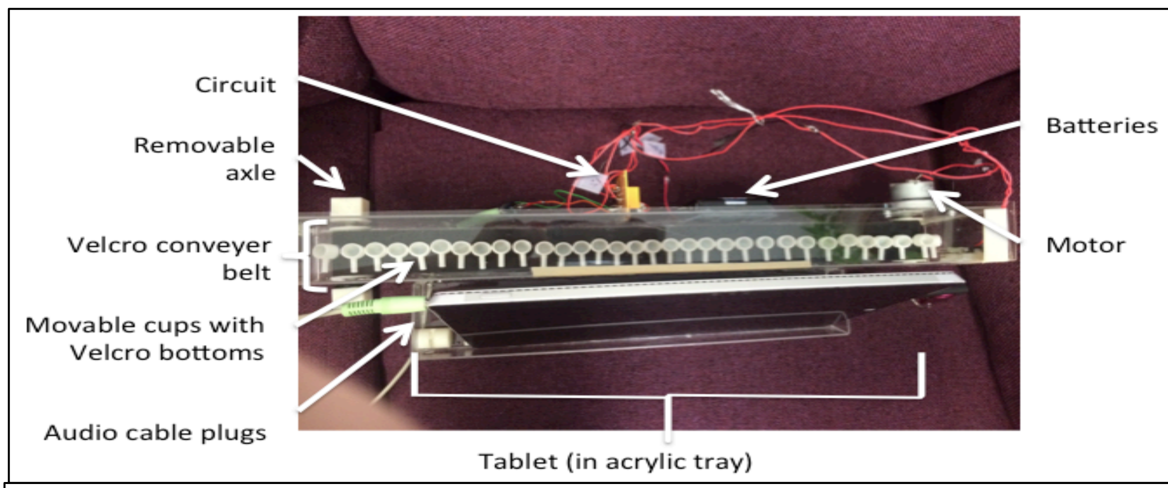

Figure 2.2- Top View with Labels

Circuit			
	Part description or number	**or main distributor**	**Price in Dollars**
Latch circuit			
	Motor, 2146505, 2 RPM, 6V. Gear ratio 340:1	Jameco Reliapro	$17.95
	Roller switch, SPDT (generic ok)	RadioShack	$2.97
	DC 3V (KS2E-M-DC3) micro relay	KEST	$1.75
Signal flow check			
	Mini LED (generic ok)	RadioShack	$0.86
	Mini LED (generic ok)	RadioShack	$0.86
	160 ohm 5% resistor (generic ok)	RadioShack	$1.09
Sound detection			
	Audio cable (generic ok)	WalMart	$2.73
	Audio jack (generic ok)	RadioShack	$3.59
	TIP 31 transistor	RadioShack	$1.99
	TIP 31 transistor	RadioShack	$1.99
General			
	AA Battery holder (generic ok)	Radioshacl	$3.25
	4 AA batteries (generic ok)	Radioshack	$1.99
	Mini perfboard circuit board (generic ok)	Radioshack	$0.99
	Electronics wire (generic ok)	Radioshack	$1.00
	Rosin core solder (generic ok)	RadioShack	$1.00
Sub total			$44.01
Delivery assembly			
	3D printed large spool roller	In house	$4.53
	3D printed small spool roller	In house	$5.00
	Wire end cap set, 2 cube	In house	$5.46
	Hanging set: 2 Hooks and 2 wire caps	In house	$2.37
	3D printed cups (70)	In house	$15.65
	10 ft, 1-1/2 in. Velcro One-Wrap Strap	Home Depot	$6.50
Sub total			$39.51
Casing			
	1/8 inch Acrylic sheet (generic ok)	Lowe's	Free in scrap bin
	Cool Shot hot glue sticks	JoAnne Fabric	$3.49
	.125 steel rod (generic ok)	Lowe's	$3.00
	Locktite plastic epoxy	Lowe's	$4.24
	"Bubble tea" straw as food chute	H.E.B.	$0.23
Sub total			$10.73
TOTAL			**$94.48**

Figure 2.3- Pricing for Feeder Robot

The bird interacted with the computer through vocalizations. If the interaction met the criteria set in the software, the tablet computer activated the belt feeder. When the bird's activities met the criteria to deliver a reward, the motor powered the belt to deliver 3-6 pieces of white millet seed. The belt moved until the empty food cup knocks a switch to put the system at rest. The schematics of the circuit can be seen in Figure 2.4 (Woodman, 2012).

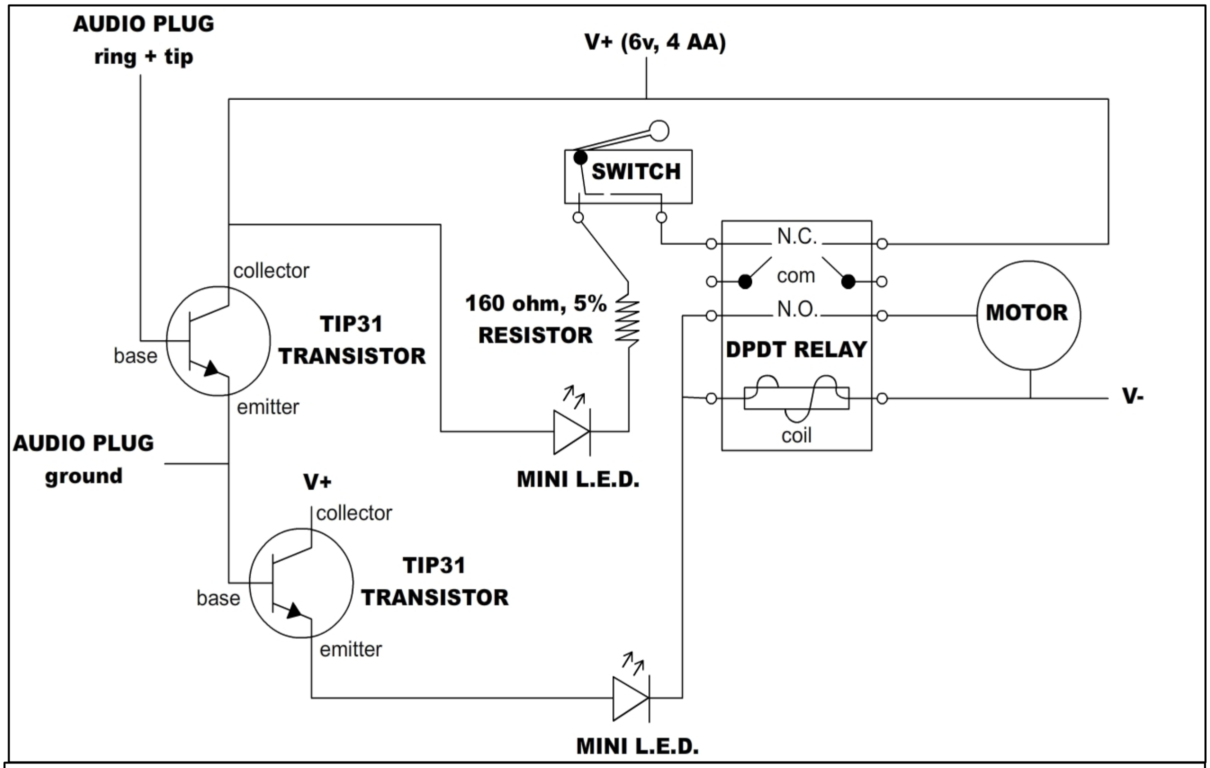

Figure 2.4 – Schematics of Circuit

Enrichment System Interactions

The enrichment system consists of a screen showing enrichment images mounted two inches outside of cages, 6 inches above the favored perch, perpendicular to the floor. The height and angle have been chosen because related species have blind spots in their visual field below beak level, but a wide field of vision above the blind area. Thus, psittacines will more readily view an object that is above the head, rather than below (Olmid & Kelber, 2009). The 2 inch distance is a “safe’ distance that Quakers cannot reach from the cage mesh. The system has a belt-driven food item dispenser enclosed in a plastic box that is inaccessible to the animals, but drops three to six white millet seeds into a feeding dish through a delivery chute. As a proof of concept, a simple skill game, based on a well-known simple stimulus-response learning behavior, was provided (Ferster & Skinner, 1957). In this game, the bird must focus to notice a 200 pixel square shown for 3 second on the monitor, which will provide a flashing image on the screen as a “bridge,” indicating food will be delivered, and then the image vanishes, similar to a whack-a-mole game. The device displayed either a square or a blank screen. These squares displayed on the screen were at a color of peak retinal absorption for maximum visualization by the birds, 503 nm green (Hart et al, 2000). When the bird responded with a vocalization above the set volume threshold while the square was available, the device automatically dispensed the white millet seed. Each game was available for a maximum of 25 minutes every session, for up to three sessions in an hour and a half period. The game system was created in Adobe Flash CS6 Professional by Constance Woodman and Jonathan Bravo. The specific flow of the game is provided in Figure 2.5.

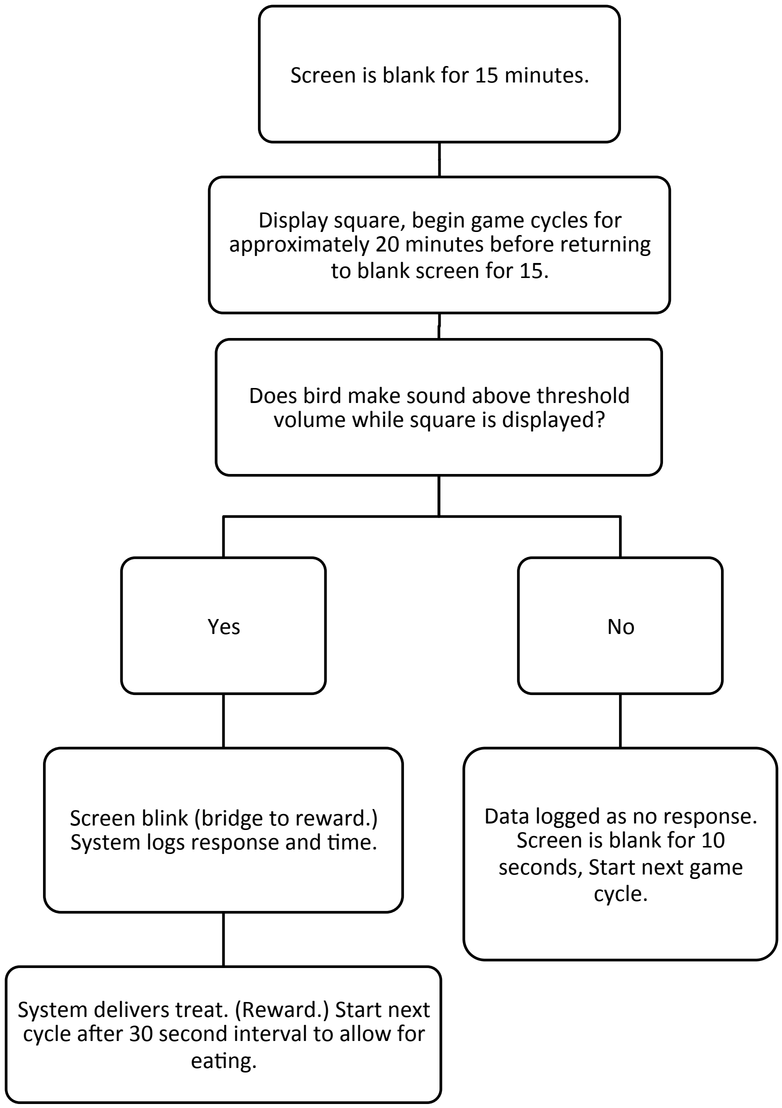

Figure 2.5, Automated training process cycle.

Data Collection

This device would automatically record how it was interacted with. Automatic data gathering is a way to keep detailed husbandry records without interrupting the daily routine. The toy, using a tablet computer as a screen and data processor, automatically collected data for 2-3 sessions within an hour and a half. Quaker parakeets are diurnal, meaning that their vision system is adapted to perform optimally in full daylight as opposed to evening crepuscular activity, as seen in some other parrots (Hall & Ross, 2006). Due to this, the monitor did not turn on during aviary darkness hours, or utilize low brightness. The toy measured the each time the square was visible to the bird, classified the bird's reaction as a hit or miss, and the time of the response. Each bird was exposed to one session where the bird was exposed to only the device, followed by full game trials. The male was exposed to eight game sessions, while the female was exposed to seven.

A Gopro video camera was used to record sessions and inform the data collected by the enrichment device. The video recordings were scanned to confirm the technology was preforming correctly, determine the time until birds were comfortable with the device, and further analyze the bird interactions during gaming sessions.

Statistical Methodology

The hit and miss data was compiled into a ratio of accuracy per trial. The activity level (total hits plus misses) per trial was divided by the period of activity length to create an activity per time score. The activity score, accuracy score, and raw hit and miss binary data were used in statistical evaluations.

A chi-squared analysis was used in order to detect whether high score per trial was contingent on sex. The results were compared to of an alpha value of 0.05 to see how subtle the factor based differences in score are ($p = 0.1, 0.05, 0.01, 0.001$).

Linear regressions were then used to analyze the accuracy and activity of each parrot as the sessions progressed. An R^2 greater than 0.5 was considered a strong trend, 0.3- 0.5 a moderate trend, and 0.0-0.2 weak or no trend.

CHAPTER III

RESULTS

Both individuals successfully interacted with the digital enrichment toy and received the rewards from the system. The toy successfully recorded data from 8 trials for the male and 7 for the female. Trials averaged 15.2 ± 6.4 min for the male and 17.8 ± 4.8 min for the female. The system was installed quickly (< 5 minutes) and easily by undergraduate students. The system collected 4.1 hours of behavioral data with a 40 minute active set up time, resulting in a six-fold return on researcher time investment, without including the time saved from automated data entry.

Each bird's interaction with the device, as represented by their high score accuracy and activity values, were automatically collected from the system. To determine whether max score (highest accuracy) differed between individuals, a chi- square analysis was used. Our hypotheses were described as follows:

H_0 - There is no significant difference in variance between the individuals

H_1 - There is a significant difference in variance between the individuals

Each individual's high score for each session and chi-squared p-value were determined in Microsoft Excel and presented in Table 3.1.

	Sex								
Score		1	2	3	4	5	6	7	8
TAMU 415	M	30.6	16.7	13.2	13.7	12.8	6.5	21.2	13.6
TAMU 410	F	18.2	12.6	14.1	17.9	15.4	22.7	28.6	9.3
									Male set as expected p<0.0001
									Female set as expected p<0.0001

Table 3.1- Chi Squared Analysis for accuracy calculated as total number of hits over total responses

The p value was less than 0.05 so the null hypothesis was rejected, and H1 was accepted. We then compared the average, maximum, and minimum scores for each bird to get a better sense of differences between the birds' activity, seen in Figure 3.2.

	Average	N (Number of Trials)	Standard Deviation	Maximum	Minimum
TAMU 415 (M)	15.2	8	6.43	30.6	6.5
TAMU 410 (F)	17.8	7	4.83	28.6	12.5

Table 3.2- Average, n value, standard deviation, maximum and minimum scores for accuracy, calculated as the number of hits over total responses.

A linear regression was then used to analyze accuracy and activity of each bird as the sessions progressed. Data is shown in Figure 3.1 and Figure 3.2.

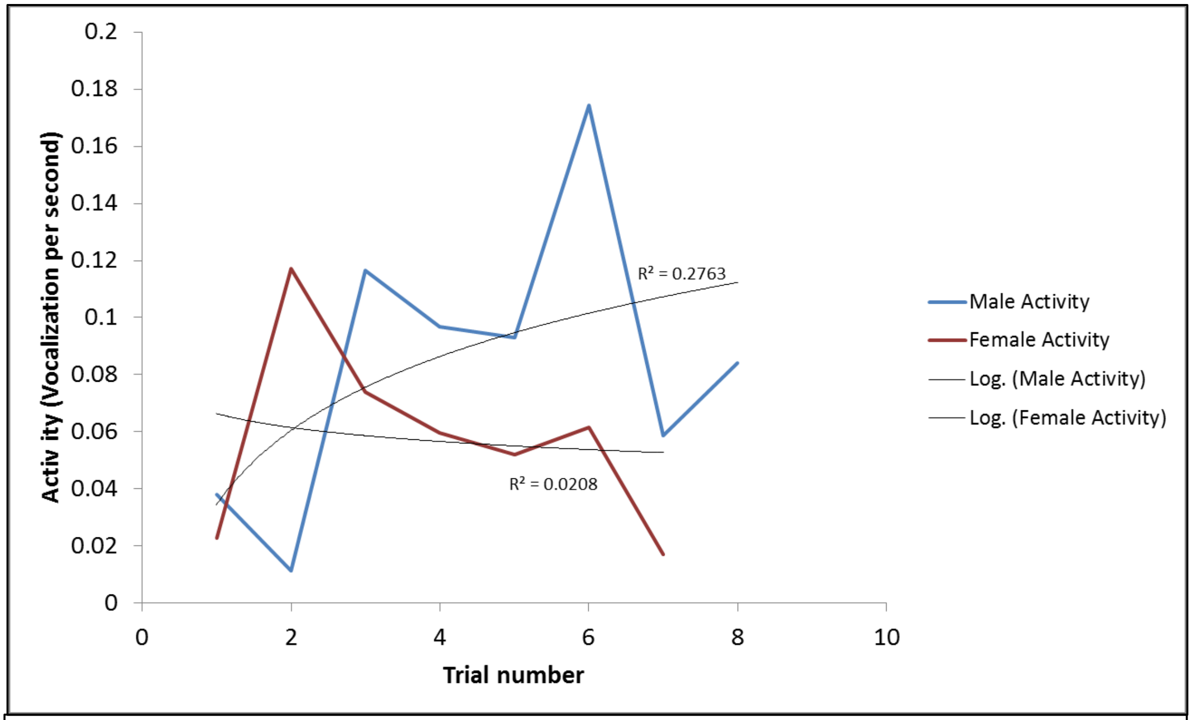

Figure 3.1- Quaker parakeet activity by trial number

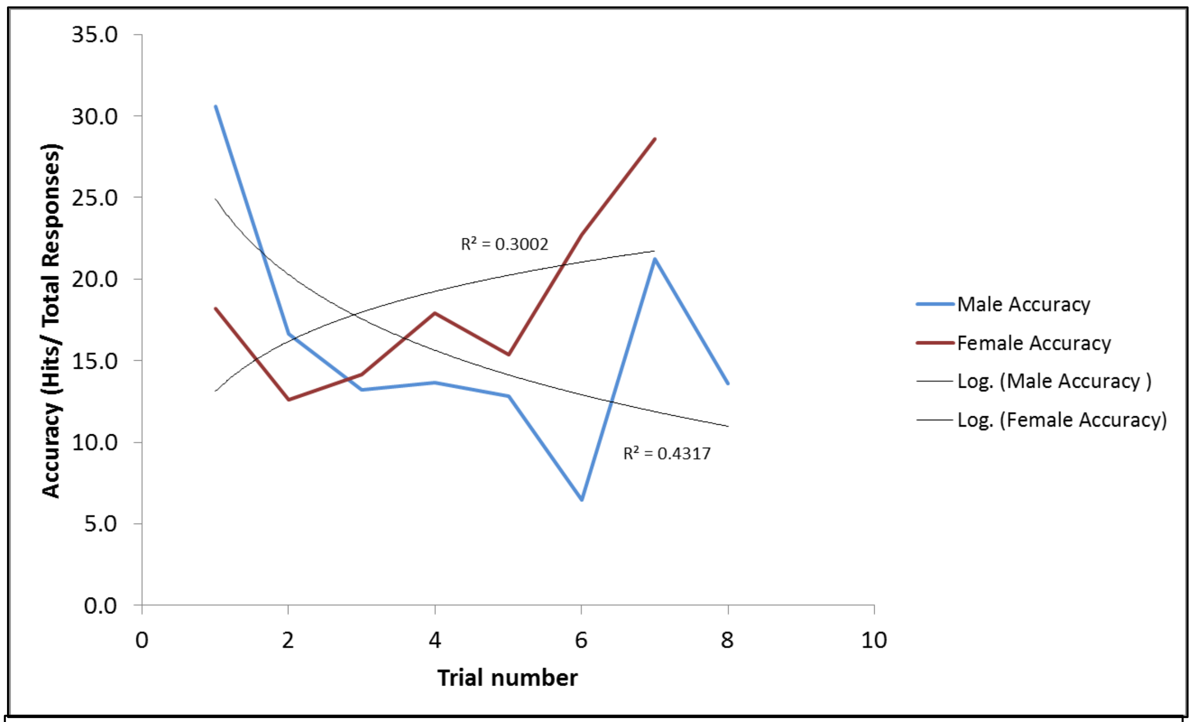

Figure 3.2- Quaker parakeet accuracy by trial number

Video data

The video data showed that birds began to show normal behavior (eating, drinking, and socializing with other birds) during exposure to the enrichment within the first game session, which is only an hour and a half. This was relatively quick compared to the time it took to familiarize the birds to other novel objects, such as a front-loading carrier. The male was more apt to interact with the screen from a close range, while the female tended to play the game from the cage floor or the walls. In Figure 3.3 the female is pictured inspecting the game from the front of the enclosure.

Figure 3.3- Female Quaker Enrichment Interaction. Because birds' eyes are on the sides of their head, this posture could indicate the bird is directly staring at enrichment device.

CHAPTER IV

DISCUSSION

The chi square analysis (Table 3.1) showed a significant difference between the scores of each individual across trials. This remained constant whether the male or female was set as the expected outcome. When comparing the birds in Table 3.2, however, we see that though the chi squared indicated significantly different scores between sexes, the birds had minuscule differences between average, maximum, and minimum scores. We therefore determined that the birds had very different method of approaching and interacting with the enrichment device over time.

The linear regressions further informed us of the tactics the birds used within each gaming session. Both birds had similar activity levels initially (Figure 3.1). The female's activity reduced over subsequent trials, while the male increased his interactions with the device. His overall activity to the device was higher than the females. This difference in style may have been due to the hormonal differences during this time of year. Male psittacines tend to be more aggressive toward objects during periods around breeding season (Seibert & Crowell-Davis, 2001). This study was conducted in April 2015, which is directly before the normal breeding period of the Quaker parakeets.

The accuracy throughout the trials was shown in Figure 3.2. Here we see that the male, while having a high accuracy score initially, fell over time, while the female increased. This may show that the female, though overall less active than the male, was steadily learning the game, while the male was less interested in the game after a very successful first session. Video data showed that the male began to show a bowing- type behavior or "dance" when a successful response was logged, which may show an emotional response to playing the game.

Overall Interactions

Both birds experienced success in this game, though the way they went about it was very different. The enrichment object was successful in providing a game in which the birds interacted, learned, and received food items. The difference in methods of interaction from each bird shows that this game does not have a standard reaction from each animal, but a positive interaction with both bird none the less. This technology needs to be tested using a larger sample of animals with more sessions per bird to make a meaningful analysis of digital enrichment as a whole. Within this study, however, the birds were successful in their games, the data were easily collected from the device, and the time necessary for the researchers to collect data was greatly reduced. This shows that this device has a great potential for the future of animal enrichment and research.

Significance in Enrichment

This project has the potential to create a new standard for animal welfare. People currently provide enrichment that requires intensive resources at every step, whether those resources are manpower or funding. This enrichment system should provide a way to supplement current enrichment techniques while being easily sustainable and cost effective. The one time, low cost of this system would ultimately be far less costly and take less time than methods that are currently in use. It can also be manipulated in order to provide different kinds of stimulation (i.e., reward exercise, or provide cognitive puzzles) for animals using the one same device. The built in data collection could provide information for the animal caretaker about the animal's frequency of use and success in each game.

Significance in Research

Automated enrichment and data collection can also change the way we collect data in various fields of research. This technology has capabilities to very cost effectively provide enrichment and research to a large group of animals. Though we are still in the process of refining the system, the entire enrichment system was created for under one hundred dollars (Figure 2.3). This product can be used for any number of animals, and could be recycled in a large selection of studies.

When a system can automatically collect data, you remove the biases and error of human data collection, creating more reliable data for statistical analysis. When this lengthy part of the research process is eliminated, it creates man-hours for the rest of the research process. Despite being a partially refined process, the six-fold reduction in time investment for data collection is noteworthy. With further refinement and multiple units collecting data, several units could act as a team of researchers, expanding undergraduate research options. This is especially meaningful for undergraduates, who are often the ones taking the most tedious data collection. When these undergraduates spend more time in in the development of a process, those undergraduates are allowed to become better researchers of the future.

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