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Number Discrimination in the Clark's Nutcracker (Nucifraga Columbiana)

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Number Discrimination in the Clark's Nutcracker (Nucifraga Columbiana)

—Lindsay Michaud (Editor: Cory McKenzie)

Research comes in many shapes and sizes. Some might imagine a setting with microscopes and complicated equipment, or even dangerous chemicals. It might require hours of long and difficult data analysis. I, however, see grey feathers and intelligent black eyes, with a personality to match. As a biomedical science, medical and veterinary science major, my research is different from a lot of other laboratories, but the work we do is just as important. The Clark's Nutcracker birds I work with are remarkably intelligent and have unique personalities that make them a joy to be around. Of particular note is their spatial memory and number discrimination ability.

The Clark's Nutcracker originates in the mountains of the Midwest and lives at high elevations of the Rocky Mountains. They are known for their extraordinary spatial memory as they store 30,000 pine seeds in up to 7,000 caches, or holes in the ground, throughout the fall, and recover them throughout the winter (Balda et al., 1998, p.34). The Nutcracker birds rely on their ability to cache nuts and relocate them in extreme environmental conditions in order to survive. It makes sense, then, that these birds have an overwhelming ability to discriminate numbers, because their evolutionary development was based on their need to survive in the mountains.

The author with one of the birds, Puck (Courtesty of Nate Landolt).

About twenty years ago, my research mentor, Brett Gibson, obtained twenty Clark's Nutcracker birds from the mountains of Colorado for his own graduate research. Nearly two decades later, the birds have provided researchers like myself with incredible insight into their superb spatial memory ability. Given the fact that the Nutcrackers store different amounts of nuts in different locations in the ground, we were curious to examine if

they have some idea of relative quantity of specific objects, such as the nuts they bury. This type of research is important to the field of psychology because it contributes to the understanding of what non-human animals know about numbers. The world of animal cognition is fascinating to many because of how little we can relate to their extraordinary senses. Discovering the true quantity discrimination of the avian species will hopefully bring more insight into how animals process information and use those numbers that they rely on so heavily in order to survive.

I first became involved in neuroscience research when I spent my sophomore year helping out in a laboratory that used rats to examine memory, but I began to develop an allergy to the rats by the end of the year. That was also around the time I became interested in applying for a research grant, and my mentor let me take on the Nutcracker birds as a project of my own. I received a Summer Undergraduate Research Fellowship (SURF) and spent the summer in the aviary on the University of New Hampshire campus studying the number discrimination abilities of the Clark's Nutcracker birds. My involvement with SURF was one of the best academic opportunities I've had the chance of experiencing at UNH.

Discovering True Arithmetic Potential

My experiment tested three Nutcracker birds in two different experiments that took place in an operant chamber. An operant chamber is a box that a laboratory animal is placed into to elicit a specific response, and a reward is given following the correct response to enforce positive behavior. Once placed in the operant chamber, we presented the birds with two virtual piles of nuts displayed on a computer screen at the front of the chamber. The birds could peck at the screen and the computer would record their responses. For the first experiment, their job was to determine which pile was bigger by pecking at it on the screen. The ratio of the two virtual pine nut piles was presented in numbers up to 9, and the difference varied. For example, a possible ratio would be 2:9, which is a large difference, and the birds would most likely not have trouble choosing the pile with nine nuts versus two nuts. However, they might be faced with the option of a 7:9 ratio, in which the decision would be harder to make as to which pile is bigger (See Figure A). We used this portion of the experiment to train the birds to choose the larger ratio.

When the Nutcrackers pecked at the correct pile of nuts (the larger pile), they were rewarded with real pine nuts. This method served as motivation to encourage the birds to perform to the best of their numerical abilities. The birds completed 72 trials each day, and by adding the results to a spreadsheet, we were able to analyze the data, see with which ratios the birds had had the most success, and conclude the basic number discrimination ability of the Nutcracker birds. The percent correct of each day was found, as well as the percent correct of the entire experiment.

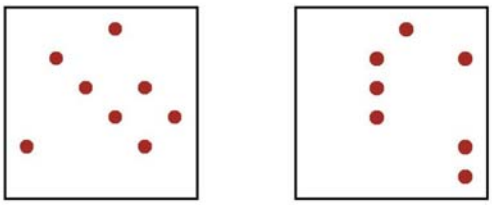


Figure A: This represents the ratio discrimination task. The Nutcracker had to choose which box contained the larger amount of dots (nuts) in order to receive a reward. The box on the left has 8 dots, and the box on the right has 7 dots. Therefore, the Nutcrackers should peck at the box on the left to receive the reward.

We then manipulated the surface area of the pile of nuts, as we wanted to see if the birds would still be able to identify the larger set. That is, we wanted to see if the birds were truly making their choices based on number and not some other dimension such as surface area. In order to see if surface area had an effect on the ability of the birds to successfully distinguish numbers, the surface area of one set of dots was either increased or decreased. For example, one of the

piles might have nine small dots that take up less surface space than four large dots. Since the birds had never been exposed to this type of program where the surface areas were inconsistent, this would give us a good idea of whether the birds could truly distinguish numbers. This experiment was set up exactly the same as the first experiment, the only difference being the surface area (See Figure B).

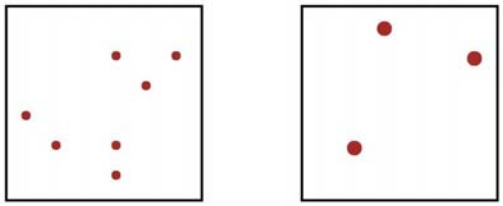


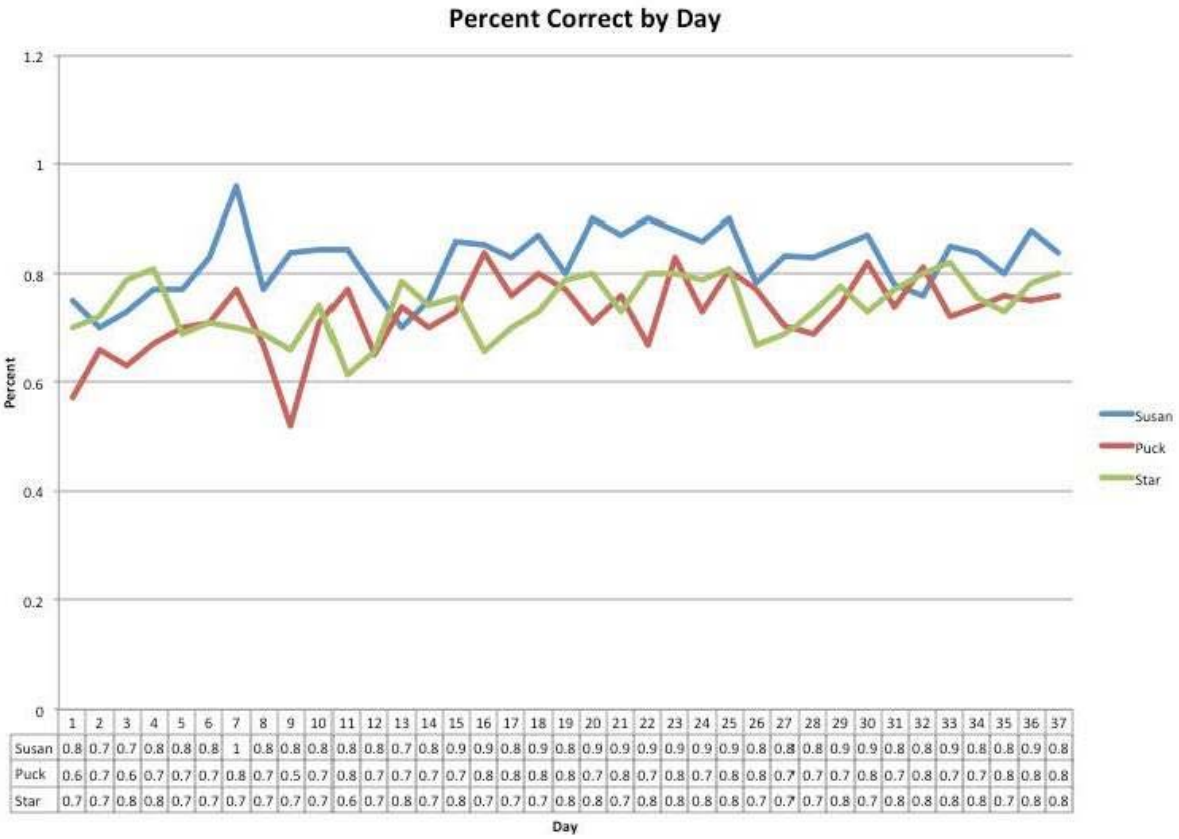
Figure B: This represents the ratio discrimination task with the surface area of one box of dots affected. The box on the left contains 7 small dots and the box on the right that contains 3 normal sized dots. Even though the surface area of the 7 dots of the left is smaller, the birds should peck it to get a reward.

Intelligence Bringing Success

The results of the surface area experiment were incredibly successful. Choosing the correct pile when the ratio is small (for example, 8:9) supports the idea that the birds most likely keep track of nuts when storing and recovering them in the wild by using numbers. Since the birds were not trained before the surface area parameters were changed, my analysis of the data obtained confirms they are using their own number discrimination abilities rather than memory.

In the end, we analyzed three sets of data for the three birds that finished the surface area experiment. The birds had percent correct of 73.7%, meaning 73.7% of the time they chose the larger pile of nuts even though surface area was changed and they had not previously been exposed to this type of program. Not only did the birds perform exceptionally, but they were successfully discriminating the dots starting from the very first day the program was changed to manipulate surface area. As expected, the birds did an outstanding job distinguishing the larger ratios such as 1:5 or 2:6. The smaller ratios, which we were more concerned about in terms of the birds being able to distinguish which box had the larger number, turned out to not give the birds much trouble at all. One of our higher performing birds, Susan, had 92% correct on the 6:8 ratio throughout the entire experiment, and an 87% on the 8:9 ratio (our toughest one), which definitely supports that she can identify the larger number even though the ratio was so small. She also had a 92% percent correct on the 5:6 ratio, and even though there were less nuts on the screen, the ratio is still small which confirms the fact that she can discriminate successfully. Another bird, Star, had a 78% on the 7:8 ratio, which was also very small and displays incredible number discrimination abilities. Our last bird, Puck, also contributed to the fact that these birds have a greater sense of numbers with 79% on the 6:8 ratio.

We were also interested in seeing how consistent the birds were with the percent correct every day. Finding the percent correct per day and then putting it into a line graph gave a clear visualization of the progress the birds were making. As shown, there was no pattern to the percent correct, as the percent would increase and decrease regularly, but it would always stay at a consistent percentage and showed a high rate of success. Figure C shows the percent correct progress of all three of the birds over 37 days of the experiment. The percent correct tracks their success of each day consisting of 72 trials. For example, if a bird were to choose the correct box 56 out of 72 trials, they would have a percent correct of 78% for that day. Finding the average of each day gave us the average of the entire experiment. Our most successful bird, Susan, averaged an 82.3% during the surface area program, which is well above 50% and therefore well above chance. Star averaged 72.7% and Puck averaged 74.1% success. This demonstrates the birds showed exceptional quantity discrimination abilities from the very start of the surface area experiment.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Susan	0.8	0.7	0.7	0.8	0.8	0.8	1	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.9	0.9	0.8	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.9	0.8	0.8	0.9	0.8
Puck	0.6	0.7	0.6	0.7	0.7	0.7	0.8	0.7	0.5	0.7	0.8	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.8	0.7	0.7	0.7	0.8	0.7	0.8	0.7	0.7	0.8	0.8	0.8
Star	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.8	0.7	0.8	0.7	0.7	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.8	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.8

Figure C: The three bird's percent correct by day when the surface area was manipulated. As shown, they are successful from the very beginning of the experiment.

This information is important for the animal cognition world because similar experiments have shown that other animals, such as monkeys and rats have only been successful discriminating numbers in small amounts. For example, given the choice to choose between two boxes with an uneven amount of apple slices, Rhesus macaque monkeys could choose the box with the larger number only if the boxes contain less than five apples each (Shettleworth, 2010, p.341). Rats can be trained to eat a fixed number of items from a pile of food before withdrawing, but only when the number involved is less than seven (Shettleworth, 2010, p.341). In contrast, the birds in my experiment performed successfully with numbers much higher than that. Since we want to determine the extent to which the birds can discriminate numbers, the next step in the experiment will be to use ratios with larger numbers, such as 20 or 30, and see if they can continue to use correct quantity discrimination abilities. This will help us to understand the true arithmetic potential of Nutcracker birds and will hopefully help us to understand how they use numbers to keep track of their caching.

Moving Forward

My experience with research has been fun and rewarding, but sometimes the journey can bring unexpected setbacks that come with working with live animals. These Nutcracker birds have had an amazing run giving

exceptional data throughout the years, but unfortunately old age has taken all but three birds. Even with the best possible veterinary care, animals can't live forever. We started the project with four healthy birds, but due to health concerns of one bird, Sony, we had to pull him from the experiment. We were able to continue the experiment and collect successful data with the three remaining birds. However, at the end of the surface area experiment in fall 2013, we experienced the very unexpected death of our most successful bird, Susan. This was a devastating blow to the lab workers who had the pleasure of working with Susan, and also had implications for follow-up research. Since the publication of this data, the experiment has since continued into spring 2014, but is running with only two birds. The birds will retire at the end of the semester.

Since I am planning to attend graduate school, I feel that by completing such a large, time-consuming experiment as an undergraduate, I have prepared myself for the higher demands of work placed on graduate students. Caring for and handling an avian species on a daily basis helped me to become comfortable with a species I didn't have much experience with and prepared me for dealing with unexpected situations I may encounter in the future. Working alone in the lab is a reality of many researchers, and I definitely wasn't immune to the loneliness that comes with it. I would spend at least five hours by myself everyday, which is why I think I had such an attachment to the birds—we kept each other company during those long, hot days of summer, and I got to know each bird individually. I'm so thankful for the time I got to spend with these amazing creatures, and I wouldn't have wanted to spend my summer any other way.

The author and Star, taking flight (Courtesty of Nate Landolt).

My research would not have been possible without the help of many generous and supportive people. I'd like to extend a thank you to the Hamel Center for Undergraduate Research staff, for their assistance with the SURF award. They gave me the opportunity of a lifetime that I am very grateful for. Thank you to my generous donors, Mr. Dana Hamel and Dr. George Wildman, who made this project possible by funding the experiment. A huge thank you goes to my research mentor Brett Gibson for helping me get involved in research when I was a sophomore and guiding me through the entire research process. His encouragement in pursuing this project made the experience worthwhile. Thank you to the ARO staff, for their constant help in taking care of the birds and keeping them healthy. Last, I'd like to thank my friends and family for their nonstop support as I continue to see where my research and education take me.

Works Cited

Balda, R.P., Kamil, A.C. (October 1992). Long-Term Spatial Memory in Clark's Nutcracker, Nucigraga columbiana. Retrieved from UNH Library Database.

Shettleworth, S.J. (2010). Cognition, Evolution, and Behavior. New York, NY: Oxford University Press.

Author and Mentor Bios

When junior **Lindsay R. Michaud** is not traveling, doing volunteer work with her sorority, Alpha Chi Omega, or conducting experiments in the laboratories of the University of New Hampshire, she lives at her family home in Presque Isle, Maine. Lindsay, who was attracted to UNH by the reputation of its pre-med program and by its proximity to her relatives, is pursuing a degree in biomedical science: medical and veterinary science. Working with rats, she developed an interest in neuroscience, and developed a sudden allergy to the rodents. Rather than hampering her career in neuroscience, this allergy opened a unique and unexpected opportunity to work with Clark Nutcracker birds during a research project funded by a Summer Undergraduate Research Fellowship (SURF) from the Hamel Center in 2013. She says that she enjoyed "creating a bond with these animals that have such unique personalities" and was deeply impressed by their intelligence. She feels inspired and prepared by her SURF experience to continue doing research in the future. "I hope I can contribute some great findings to the medical world," she says. Lindsay plans to continue her education at the graduate level in optometry school after she completes her undergraduate career in May 2015.

Brett Gibson, associate professor of psychology, has taught at the University of New Hampshire for ten years. Specializing in animal cognition, learning, and behavior, he has been working with the Clark Nutcracker since he was researching his own dissertation in the mid-1990s. His past research focused primarily on the bird's memory and navigational abilities, but in recent years he has worked with students to investigate the Nutcracker's knowledge of numbers. "These birds cache and recover tens of thousands of seeds each year that they use as energy for survival," he marvels. "We think that having a keen sense of number may help them be more efficient during the cache and recovery process." He was surprised by the success of this experiment and how the birds' counting abilities showed through almost immediately. Gibson has mentored numerous students in his lab, many of whom have gone on to graduate school. Enthusiastic about Inquiry's potential for helping science students to reach a broader audience in their writing, he notes, "One of the great challenges scientists have is conveying their research in an accessible form to the lay population." Gibson is very thankful for the support that undergraduate research receives at UNH. Many people might be tempted to cut funding for projects about birds having a sense of numbers, he says, but the experience that students receive doing this kind of original research is integral to their development as scientists. "Students like Lindsay go on to fill positions at the highest levels of our society," he concludes, "and the hands-on training they get in the lab is invaluable."

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