The Application of Citizen Science to an Undergraduate Research Project on Canine Cognition

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Abstract

Animal research provides meaningful insight into animals' skills and abilities, further enhancing our care for and understanding of them. However, performing authentic animal research in an undergraduate class is difficult because of cost and limited resources. One solution to this challenge is citizen science. Citizen science is a form of research conducted by members of the public who perform experiments and gather information for researchers, allowing for wide-scale data collection with minimal cost associations. Thus, an experiment using the citizen science approach was performed in Animal Bioscience 360 at the University of Saskatchewan to determine if there were cognitive differences in groups of dogs. Teams of two students performed cognition tests on their own dogs and tested four aspects of cognitive ability: memory, object permanence, perspective-taking, and response to human cues. Together, the class tested 42 dogs and uploaded the experimental data to Excel. Students developed hypotheses to test whether dogs differing in age, gender, breed, obedience training, or household status had different cognitive profiles. There were no significant differences in cognition except that dogs living in single-dog households yawned significantly more often in response to human yawning than multi-dog households ($P \leq 0.05$). The citizen science approach provided 61 students with an authentic research experience and improved their writing and numeracy skills. Undergraduate research experience assists in practical skill development, improved academic performance, and degree completion. Citizen science enhances participants' knowledge of the research area and provides a level of transparency toward scientific research.

Keywords: dog, cognition, citizen science, undergraduate research

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Introduction

Undergraduate research gives students an opportunity to expand their knowledge while developing practical skills. The students get to work alongside professors and graduate students within their college and obtain relevant hands-on experience. Involvement in undergraduate research is seen to improve academic performance and degree completion (Gregerman et al. 1998; Hathaway et al. 2002; Kinkel and Henke 2006). However, for many students, finding such experiences can be difficult, particularly in disciplines that involve animal research. Research on animals at the University of Saskatchewan requires approval by the Animal Research Ethics Board on campus. Approval by the Animal Research Ethics Board requires showing that the research has scientific and pedagogical merit and that the researcher has applied the 3Rs principle: Replacement, Reduction, and Refinement. Using student-owned dogs replaced the use of any laboratory animals while still giving students the opportunity for hands-on data collection and a valid research experience. Animal ethics is important in any animal-based study, including those using citizen science. Citizen science works to maintain this status; however, it is able to bypass the time-consuming approval processes that other animal-based studies would require. Another constraint in conducting undergraduate research is the lack of funding. There are 80-100 students in the Animal Science/Bioscience programs at the University of Saskatchewan, and this would require a large number of animals to give students a meaningful, hands-on research experience. The cost of housing, feeding, and caring for these animals would be prohibitive. One approach to bypass the constraints of time, the number of animals used, and the cost is through the use of citizen science.

Citizen science can be defined as the collection of data by volunteers working with professional researchers. This form of research allows non-scientists to participate in research and supplies the researchers with data that would be difficult to collect without a big group of individuals. An example of citizen science is obtaining annual bird counts (Sullivan et al. 2014). A large number of volunteers can provide a sizeable amount of data that can be used to assess bird populations. This large-scale data collection by volunteers decreases the cost and increases the scope of research projects. Another example of citizen science is the collection of dog cognition data (Laughlin et al. 2015). Research in dog cognition has exploded in the last two decades because, in many ways, dogs are cognitively more similar to humans than primates (Hare et al. 2002; Hare and Tomasello 2005; Cooper et al. 2003; Miklosi et al. 2004; Ward and Smuts 2007). However, using a large number of dogs in a university lab to measure their cognitive abilities is infeasible, and is why having individuals perform cognitive tests on their own dogs offers a solution to this problem. Citizen science also provides a model for giving undergraduate students an authentic animal research experience.

Animal Bioscience 360 (Canine and Feline Science) is an elective course for students in the Animal Science/Bioscience programs at the University of Saskatchewan. Previously, there were demonstration laboratories that involved presentations of police dogs and dog obedience training. Student evaluations of the course commented on the lack of hands-on experience with animals. To address this issue, a citizen science approach to gathering information on dog cognition was implemented in 2019 to allow the 61 students in the class to interact with dogs, collect data, and experience animal research. This paper is based on data generated during this process. A total of four cognitive parameters were selected based on their ability to be measured in a simple and non-subjective manner: memory, object permanence, perspective-taking, and response to human cues. Additionally, these parameters give good insight and a diverse analysis of the cognitive abilities of the animals. Accurate data was obtained, and this data then allowed the students to analyze several different divisions of the dogs' profiles (age, gender, neuter status, breed, and household status). The analysis showed the effect of these divisions on canine cognition and validated citizen science as a meaningful tool in undergraduate research.

Canine cognition is an ever-expanding topic of interest amongst both researchers and everyday dog owners, making it a beneficial topic for the application of citizen science research. This approach allows researchers to collect meaningful data while allowing the owners to be involved and gain knowledge as well. Canine cognition, and animal research as a whole, is suitable for the use of citizen science as it allows the tests to be performed in familiar environments for the dogs, with people they trust. With such an approach, the results are more consistent and meaningful as the dogs' behaviour is not altered in response to the setting, making it a more accurate reflection of their true and normal abilities. Additionally, the results are collected on a much greater scale than normal laboratory parameters would allow. The restraints of the laboratory setting (space, test subjects, and people) limit the research on this topic to date. Citizen science removes these constraints while contributing meaningful data to the topic of canine cognition. This study aimed to examine the use of citizen science as an approach to engage undergraduate students in animal research.

Materials and methods

This research was performed in Animal Bioscience 360.3 during term 2 of the 2018-19 academic year of the University of Saskatchewan. The instructor of the course was Dr. Murray Drew, a Professor in the Department of Animal and Poultry Science. The Animal Care Committee confirmed that animal care approval was not required because the experiment involved dogs working in their homes with their owners. The citizen science approach was used to obtain data from a total of 42 dogs. The time and setting of these tests were left to the discretion of each owner. The only requirement was that once the test began, the experiment had to be completed at that time with no breaks. Each group consisted of 2-3 people who acted as the tester or observer(s) during the experiment so that every student took part in at least one test. Demographic information on the dog's breed, age, sex, neutering status, whether they had taken obedience classes, and the number of dogs in the household was recorded. The test consisted of ten games (Table 1) described in Laughlin et al. (2015). These games can be categorized into four areas of cognitive ability: memory, object permanence, perspective-taking, and response to human cues. Groups performing the tasks were supplied with a set of written and video instructions and a data collection sheet. The objective was to minimize variation in how the tasks were performed and how the data was recorded and eliminate bias between the groups.

The data collected from each group were uploaded to an online survey (SurveyMonkey) and was compiled in an Excel spreadsheet upon completion. Each student participating in this research project was given a choice of several hypotheses to test for their paper; they could look at the dog's training experience, their gender, household status, age, or whether they were purebred/crossbred to see how this influenced the dog's cognitive profile.

Individual dogs were considered the experimental unit. The experiment variables were analyzed using analysis of variance (Microsoft Excel for Mac; Version 16). Treatment means were considered significantly different when $P \leq 0.05$.

Results

The cognitive profiles of dogs were assessed based on a series of ten tests categorized into four areas of cognitive ability: memory, object permanence, perspective-taking, and response to human cues. There was only one significant difference across all the hypotheses (looking at the dog's training experience, their gender, household status, age, or whether they were purebred/crossbred to see how this influenced the dog's cognitive profile). The yawning experiments showed no significant difference between dogs of the training class, breed, gender, and age groups ($P > 0.05$). However, in contrast to the rest of the data, these test results were seen to be significantly different between dogs that had another dog in the house and those that did not ($P \leq 0.05$; $P = 0.024$). The delayed memory test was the primary test under the "memory" category and was not significantly different between obedience-trained dogs, those that lived with and without another dog, males and females, young and old dogs, and crossbred and purebred dogs ($P > 0.05$). Memory vs. smell tested both memory and object permanence and showed no significant difference between any of the sets of dogs ($P > 0.05$). Similarly, memory vs. pointing, testing both memory and response to human cues, was not significantly different amongst the groups across all categories ($P > 0.05$). In the tests specifically looking at response to human cues, arm and foot pointing, no significant differences were seen in any of the categories; $P > 0.05$ for both sets of data. Lastly, and consistent with the rest of the results, in the four tests looking at perspective-taking (watching, back turned, eyes closed, and watching again), $P > 0.05$ for each, indicating that none are significantly different amongst the groups of dogs in all categories.

Discussion

The goal of the games played in this experiment was to determine a dog's ability to respond to human cues even while testing the other aspects of cognition (object permanence, memory, and perspective-taking). Despite many studies looking at canine cognitive profiles and the influence of several demographic variables on the topic, few studies have found cognitive differences based on the demographic variables examined in this experiment. The lack of pre-existing information on the demographic variables analyzed in this experiment is likely a result of how specific and focused the parameters are.

The results obtained from previous studies analyzing male vs. female cognitive profiles in dogs proved to be consistent with the results obtained from this experiment, showing no significant effect of gender on canine cognitive profiles. In a study performed by Duranton et al. (2015) analysing the difference amongst male and female dogs by testing physical cognition, males initially showed significant success over the females. However, when re-tested, the females were found to be more successful than the males (Duranton et al. 2015). This inconsistency may speak to females' enhanced ability to remember the successful strategy of problem-solving, thus making them more successful when re-tested.

Scandurra et al. (2018) found differences in male and female cognition within certain areas; however, while males surpassed the females in some respects, such as spatial skills, females surpassed the males in others such as

Table 1: The numbers of trials, the order of the tasks as presented to all participants, task names, and general methods (after Laughlin, 2015).

Task	# of trials	Test description
Yawn Control	1	Participant says "yellow" every 5s for 30s
Yawn Experiment	1	Participant yawns every 5s for 30s
Eye Contact	3	Participant holds food to their face and records when/if dog breaks eye contact during 90s timeframe
Arm Pointing	6	Participant extends their arm and index finger toward one of the two food pieces placed on the floor and allows dog to retrieve
Foot Pointing	6	Participant extends their foot toward one of two food pieces placed on the floor and allows dog to retrieve
Watching 1	1	Participants face their dog, verbally forbid them from taking food, and record when and if they retrieve food during 90s countdown
Back Turned	2	Same as watching, only participant turns their back after placing the food
Eyes Covered	2	Same as watching, only participant covers their eyes with their hands after placing the food
Watching 2	1	Participants face their dog, verbally forbid them from taking food, and record when and if they retrieve food during 90s countdown
Memory vs Pointing	6	Participant places two cups and shows dog food being hidden under one of the two. Participant then points at the empty cup
Memory vs Smell	6	Participant places two cups and shows dog food being hidden under one. Participant occludes dog view as the food is moved to be hidden under the previously empty cup
Delayed Memory	4	Participant places two cups and shows dog food being hidden under one. Increased time delays after placement (60, 90, 120, and 180s) until dog is released to search for the food

cooperative skills. These variations made it difficult to establish an overall difference in the cognitive abilities of male and female dogs. Such results were expected from this study since the neuter status of these animals, although considered alongside gender, was not taken into consideration on its own; females and males, both spayed and in-tact, were analyzed together since not enough in-tact animals were present to make their own category within each gender. This variable created variation within the two categories since neuter status is well known to influence behaviour of animals. The variation, therefore, takes away from the probability of obtaining significant results. Furthermore, the previous literature analyzing the effects of gender on canine cognition validates these expectations, as no significant differences have been recorded.

Many studies support the hypothesis that cognitive ability in dogs becomes impaired with age (Nielson, J.C. 2001; Milgram 2003; Hart, B. 2001). However, the age variation within our experiment was extensive; the categorization between "young" and "old" dogs was an arbitrary decision made by the individual analyzing the results. This categorization made it difficult to compare our results to that of previous literature. Future experiments might benefit from standardizing the categorizations between "young" and "old" or simply treating age as a continuous variable for future research to avoid such wide variation. The lack of difference amongst the groups obtained in our results suggests that dogs are quick, attentive learners who retain what they learn. Even the younger dogs that may still be in the process of training have the same cognitive abilities as those that have been trained for many years. However, a definitive effect of age on cognitive profile was not determined with the experimental groups used. These results are likely due to the wide age-range used in each category, as well as the idea that young and old dogs have similar cognitive abilities as previously mentioned in relation to their duration of training.

Dogs have been domesticated by humans over several years, and with that, have been selected for cue-following skills and communicative abilities (Wobber 2009). With this domestication, even further subsequent selections have occurred in certain breeds (working dogs in particular) that encourage more advanced cognitive abilities (Wobber 2009). These selection processes have led to a difference in cognitive abilities amongst different breeds of dogs. Although breeds are seen to have varying intelligence levels and behaviour, there was a variety of breeds (both crossbred and purebred) used in this experiment. This diversity resulted in substantial variation within our breed categorizations in our results and an inability to establish a significant difference amongst the two groups. Had specific breeds been used for categorization as opposed to being grouped solely into crossbred and purebred, more significant differences would have been expected. The blending of multiple breeds within one category likely worked to counteract the different cognitive abilities presented by each individual animal due to the drastic breed differences that are known to exist in this area (Wobber et al. 2009).

In this experiment, cognition was measured on an individual basis, not a demographic basis. Because of this, it is difficult to establish a direct effect on training and the presence of another dog on the cognitive profiles of the dogs being tested. A lack of research exists on these specific variables in terms of canine cognition, making it challenging to analyze what was to be expected from these results. The significant difference seen in the household status category during the yawning experiment may speak to the influence of the environment on the animal's cognitive abilities. Perhaps by the dogs being more distracted with other animals present, they were less attentive towards their owners and therefore did not respond to the test cues to the same extent as single-household dogs. Another possible explanation of this difference could be the level of dependence sole animals have on their owners; dogs with other conspecifics in their environment may learn to be more dependent on one another and, as a result, less dependent on their owner. These, however, are all speculative answers that require further research to verify.

A limitation in the analysis of the data collected was the broad division of many of the categorizing groups. Since many of the decisions regarding group division were arbitrarily made by the analyzer, it was difficult to compare results to that of previous literature. More significance could have been found in the results had there been definitive, detailed groupings. This would give the possibility for more distinct results to be obtained. Many of our categories overlapped or led into other categories that have been found to show differences in cognitive profiles in dogs. The blending of those groups, however, masked these differences in our experiment. In future experiments, it may be beneficial to constrain the dogs being analyzed to certain ages, breeds, neuter statuses, or with more strict environmental boundaries. These constraints would allow for a more effective analysis of the effect of each of these parameters. By making these changes, it would facilitate better data analysis and interpretation of the results as well as increase consistency.

Although the majority of the tests conducted demonstrated differences amongst groups that were not significant, the compiled data was utilizable for analysis. The data collected from each group and the information provided about the dog gave results that allowed the testing of several hypotheses. With this, citizen science in both undergraduate and animal behaviour research is shown to be a successful and practical method of data collection. Additionally, it is easy, accessible, and cost-efficient. This approach is a valuable method of providing an authentic animal research experience to undergraduate students. A recent news feature in Nature recognizes the growing popularity and ambitions of citizen science in many areas beyond just animal cognition; areas such as assessing radiation levels, vector-borne diseases, and calibrating flood models (Irwin, 2018). Citizen science is working to satisfy the societal drive for data, increasing connectedness, and improving the transparency and accessibility of science in several different disciplines (Irwin, 2018).

The full potential for citizen science is just beginning to be understood (Bonney et al. 2009). It is a good experience for students and has been confirmed to produce reliable data (Cohn 2008). Citizen science is a worthwhile method for giving students animal research experience as it provides a well-rounded insight into what research entails. Such research facilitates hands-on experience at minimal cost, provides students with a large data set to analyze, and provides the opportunity to practice scientific writing. Therefore, citizen science provides a beneficial, effective, and fulfilling animal research experience to undergraduate students.

Had it not been for citizen science, our class would not have been able to conduct this experiment. By allowing students to collect data on their own dogs and to work in groups where every individual could be involved, they were able to gain hands-on animal research experience - something which many students are never given the opportunity to do. It is difficult to obtain a large sample size of animals under the restraints of the traditional laboratory setting, such as limited space and high costs of maintaining a large number of animals. Citizen science is one way to lift these barriers because it allows widespread data collection with minimal costs and allows researchers to carry out a real experiment and obtain real data – data that has been shown to be valid and meaningful.

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Supplementary Material

Table S1: The results of dog cognition tests for dogs who did vs did not attend training classes, 5 years of age or younger vs older than 5 years of age, crossbred vs purebred, without other dogs in the house vs with other dogs in the house, and female vs male.

Group	Yawn Control	Yawn Experiment	Eye Contact	Arm Pointing	Foot Pointing	Watching 1
Training classes	0.063 ± 0.25*	0.25 ± 0.68	40.20 ± 31.80	4.25 ± 1.39	4.19 ± 1.38	37.00 ± 38.76
No training classes	0.20 ± 0.65	0.40 ± 0.65	50.77 ± 26.20	3.96 ± 1.72	4.56 ± 1.33	39.40 ± 35.30
P value	0.42	0.48	0.26	0.57	0.39	0.84
≤5 years	0.20 ± 0.65	0.40 ± 0.71	48.50 ± 28.16	4.24 ± 1.54	4.36 ± 1.22	41.04 ± 38.11
>5 years	0.0588 ± 0.24	0.24 ± 0.56	44.70 ± 29.24	3.82 ± 1.63	4.53 ± 1.50	33.00 ± 33.32
P value	0.40	0.43	0.67	0.41	0.69	0.49
Crossbred	0.21 ± 0.66	0.46 ± 0.72	45.37 ± 23.82	3.92 ± 1.50	4.5 ± 1.22	32.71 ± 35.22
Purebred	0.056 ± 0.24	0.17 ± 0.51	49.04 ± 34.01	4.28 ± 1.67	4.33 ± 1.50	44.56 ± 37.02
P value	0.35	0.15	0.68	0.47	0.69	0.30
1 dog	0.11 ± 0.32	0.58 ± 0.84	49.64 ± 30.71	4.21 ± 1.4	4.32 ± 1.45	35.95 ± 34.77
>1 dog	0.17 ± 0.65	0.13 ± 0.34	44.71 ± 26.64	3.96 ± 1.72	4.52 ± 1.24	39.30 ± 37.78
P value	0.68	0.024	0.58	0.61	0.62	0.77
Female	0.19 ± 0.62	0.37 ± 0.69	49.10 ± 26.50	4.07 ± 1.52	4.37 ± 1.24	39.48 ± 36.84
Male	0.067 ± 0.26	0.27 ± 0.59	43.05 ± 31.87	4.07 ± 1.71	4.53 ± 1.51	34.73 ± 35.63
P value	0.49	0.63	0.51	0.99	0.71	0.69

Group	Back Turned	Eyes Hidden	Watching 2	Memory vs Pointing	Memory vs Smell	Delayed Memory
Training classes	40.98 ± 37.19	36.36 ± 38.57	39.75 ± 40.70	3.38 ± 2.60	1.38 ± 1.59	2.75 ± 1.34
No training classes	32.49 ± 32.77	27.13 ± 30.21	31.80 ± 31.71	2.92 ± 2.04	1.20 ± 1.26	3.08 ± 1.15
P value	0.45	0.40	0.50	0.54	0.70	0.41
≤5 years	36.60 ± 39.11	35.26 ± 38.67	37.08 ± 37.86	2.84 ± 2.39	1.24 ± 1.54	3.2 ± 1.19
>5 years	33.00 ± 26.41	22.67 ± 22.52	30.06 ± 31.10	3.29 ± 2.14	1.24 ± 1.15	2.65 ± 1.22
P value	0.74	0.23	0.53	0.53	0.99	0.15
Crossbred	38.38 ± 35.36	30.43 ± 33.98	31.63 ± 34.83	2.50 ± 2.40	1.21 ± 1.32	2.96 ± 1.16
Purebred	30.80 ± 33.13	29.82 ± 33.47	37.72 ± 36.04	3.72 ± 1.96	1.28 ± 1.49	3.00 ± 1.33
P value	0.48	0.95	0.58	0.085	0.87	0.91
1 dog	31.53 ± 32.70	29.25 ± 33.15	35.42 ± 34.35	2.68 ± 2.19	1.47 ± 1.31	3.00 ± 1.05
>1 dog	38.10 ± 35.87	30.92 ± 34.24	33.26 ± 36.36	3.30 ± 2.36	1.04 ± 1.43	2.96 ± 1.36
P value	0.54	0.88	0.85	0.39	0.32	0.91
Female	38.76 ± 35.52	33.34 ± 35.02	31.78 ± 35.68	2.74 ± 2.52	1.19 ± 1.24	2.89 ± 1.09
Male	28.59 ± 31.86	24.45 ± 30.42	38.67 ± 34.64	3.53 ± 1.73	1.33 ± 1.63	3.13 ± 1.46
P value	0.36	0.41	0.55	0.29	0.74	0.54

*Means ± standard deviation; Means were considered significantly different when $P \leq 0.05$)