



The Use of Robotic Animals to Increase Interest in Comparative Psychology

Divija Brahmandam¹, Riley J. Wincheski², Carl D. Latino¹, and Charles I. Abramson²

¹*Department of Electrical and Computer Engineering, Oklahoma State University, U.S.A.*

²*The Comparative Psychology and Behavioral Biology Laboratory, Department of Psychology, Oklahoma State University, U.S.A.*

This project focuses on the use of robots to increase student interest in comparative psychology. Robots facilitate the development of critical thinking skills, problem solving ability, and apparatus design. Moreover, as behavioral apparatuses become more sophisticated, the use of robots can help increase the interactions between comparative psychologists and engineers. We provide details on how to construct a robotic squirrel. Our squirrel is a ground-based motion robot driven at variable speeds utilizing slip steering. It supports an on-board video system to record and monitor various behavioral patterns of small animals, primarily squirrels in this project, from a distance. It also includes an audio system, which can record and playback sounds to the animals, and a simple robot arm-like structure with two degree of freedom controlled by servos. An Android smart phone application was developed to control the motion and speed of the robot and other operational controls in the system, such as record, playback control, and movement of the robot arm. We suggest that robots can be used as a source for independent projects, be incorporated into a class lecture on behavioral apparatuses, and/or be designed as a class project.

Keywords: comparative psychology, teaching, robots

This article is the first to suggest robots can be incorporated in the teaching of comparative psychology. While comparative psychology has not yet embraced the use of robots for teaching and research, related fields such as behavioral ecology, experimental biology, and entomology are making great progress in using robots to study a variety of animal-human interactions (Colot et al., 2004; Krause et al., 2011; Romano et al., 2019). More recently, it has been suggested that robots can help to better understand animal cognition (Frohnwieser et al., 2016).

The Frohnwieser et al. (2016) paper begs the question, “Where are the students trained in robotics going to come from?” Our answer is, “From students of comparative psychology.” However, to our knowledge, there are no courses in comparative psychology that incorporate robots into the training of our students. This is unfortunate because, once again, researchers in other disciplines believe that they can conduct comparative psychological investigations without, at least, a working knowledge of comparative psychology. If this situation is not addressed, we risk becoming irrelevant as a scientific discipline.

Robots have much to recommend them for the teaching of comparative psychology. First, the use of robots can bring comparative principles to life by implementing engaging, inquiry-based learning experiences. If students are given the opportunity to design their own robot, they can express their creativity and enhance their research skills in behavioral observation and experimental design. Second, in designing and programming their robot, students learn a variety of important skills related to STEM. These skills include those associated with engineering, physics, and mathematics. Third, students will have an important new skill set that will give them an edge not only in applying to graduate school but also in the business world. In regards to the latter, students will acquire practical skills important to the robotics industry, such as logic, problem solving, and perseverance. Fourth, the skills that students learn regarding robotics will constitute the next generation of comparative psychology students. Who better to help engineers design robots than a comparative psychologist?

There have been many areas of research that demonstrate that animal behavior could be studied and influenced by the help of robotic technologies. The collective and individual behavior of animals is the main question addressed by robotic animals. For example, robots are used to study group interactions in cockroaches and chickens (Colot et al., 2004; Gribovskiy et al., 2010).

Once the robots are accepted into a habitat and/or social structure, many types of experiments can be performed including exploring the collective response of a group of animals to the robot in their habitat and individual responses toward the robotic animal. Recently, researchers using a sophisticated robotic fish were able to conclusively demonstrate that the schooling behavior contains hydrodynamic benefits which permit them to save energy (Li et al., 2020). While it has been known for centuries that some fish swim in schools, the reason for this behavior has never been adequately explained.

Physical resemblance of robots to the target animal may be a factor influencing the acceptance of the robot systems into animal groups. However, results of an experiment conducted to control social aggregation in cockroach robots called the InsBots were designed to resemble cockroaches only in their size and not in their appearance. The InsBots were accepted by the cockroaches because of a special pheromone spread on the robots that is similar to the pheromones secreted by cockroaches (Colot et al., 2004).

However, there are other data showing that resemblance plays a key role in the acceptance of the robots into an animal group. According to a paper introducing the Robofish, a robot was designed simulating the morphological details of a three-spine stickleback. This Robofish was placed in a tank with other sticklebacks. Resemblance appeared to increase the probability of accepting the robots in the stickleback group by not causing an alarm reaction (Jolyon et al., 2010).

Inspiration for the Project

The inspiration for developing a low-cost robot was the Mercury Remote Robot Challenge (MRRC) formerly held annually at Oklahoma State University. The MRRC is an event where robots are operated from a distance in excess of 50 miles. Many of the competitors operate their robots from their home countries (such as Brazil, Colombia, Japan, and Mexico). The event was created and hosted annually by Dr. Carl Latino of the Electrical and Computer Engineering Department at Oklahoma State University. Robots entered into the MRRC competition were built by the competitors from universities and robotic clubs. The robots ranged in cost from a few hundred to several thousands of dollars and were required to be rich in features, such as capable of overcoming obstacles, picking up and throwing objects, video capabilities, and remote control. When observing the competition for a number of years, the idea naturally presented itself whether robots can be adapted for the teaching of comparative psychology. To make robotic animals accessible to all, we created an inexpensive (approximately \$200 without the phone and laptop), small remote-controlled animal robot.

The Squirrel Robot System

Our robot was constructed as a tool for approaching and interacting with small animals (e.g., squirrels). The robotic squirrel system can be remotely operated to move and record and playback audio/video and employs a two-degree-of-freedom robotic arm. The robotic arm can be used, for example, to administer acorns and other items to squirrels.

For this project, a worldwide communication system was not necessary and a short-range Bluetooth technology was employed. An attempt was made to package and enclose all the components in a model that loosely resembles the structure of a squirrel. Resemblance was not a primary consideration.

The squirrel robot system is a remote-controlled, ground motion-based robot system, designed to allow the study of squirrel behavior in its environment. It has an audio system to record from and playback the sounds to the animal and a video system, which supports a live streaming video and saves it for future references. The robot also has a two-degree-of-freedom robot arm, controlled by servos to act as a nut-delivery system. Three

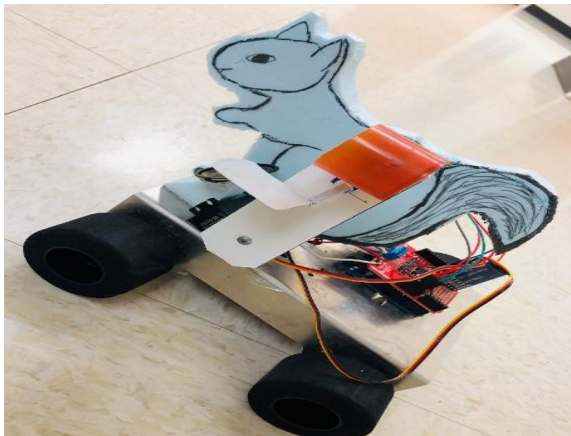
major components comprised this system: a robot, a smart phone application, and a laptop for visual feedback from the robot.

Apparatus Components

The remote controlled Arduino robot is expected to provide assistance in studying animals in the wild by performing certain specific operations. Every animal study has different requirements based on the ecosystem. Our project focuses mainly on squirrels found around the Oklahoma State University campus. Figure 1 shows a replica of our squirrel. It was constructed out of cardboard, but other methods could be used, such as attaching a toy squirrel.

Figure 1

Remote-controlled Squirrel Robot System



Replicas of squirrels and many other animals are easily found on the internet. Figures 2 and 3 show a block diagram of our overall system and video system, respectively. The system requirements include video recording, audio recording and playback, locomotion, and a system to deliver an acorn or a nut in the direction of the animal. The robot moves at a speed of 1.3 ft/s (0.396 m/s).

Figure 2

Block Diagram of the Bluetooth Robot System

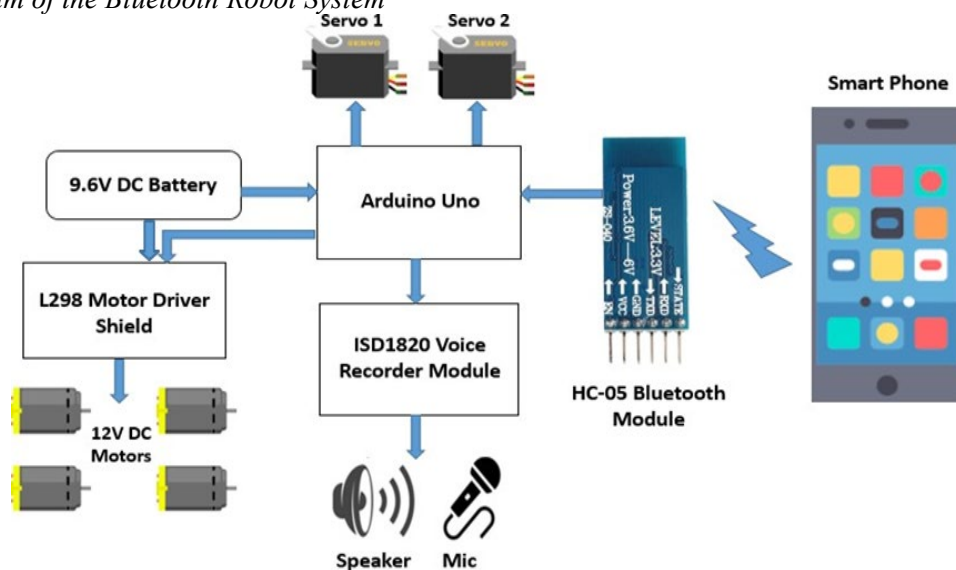
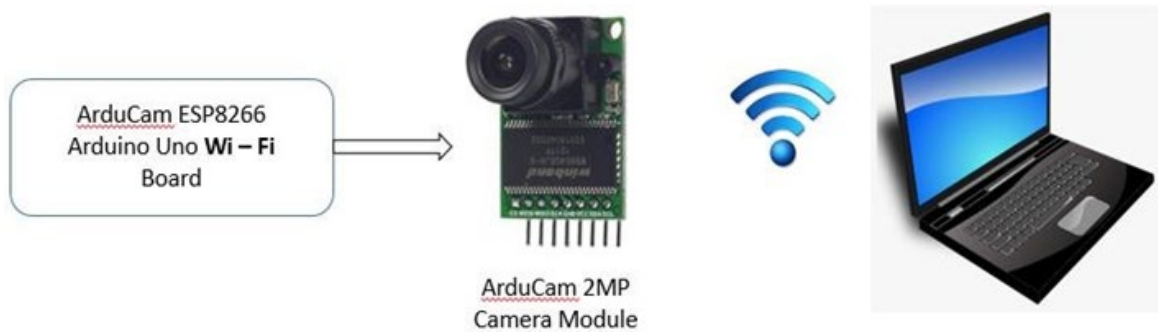


Figure 3

Block Diagram of the Video System



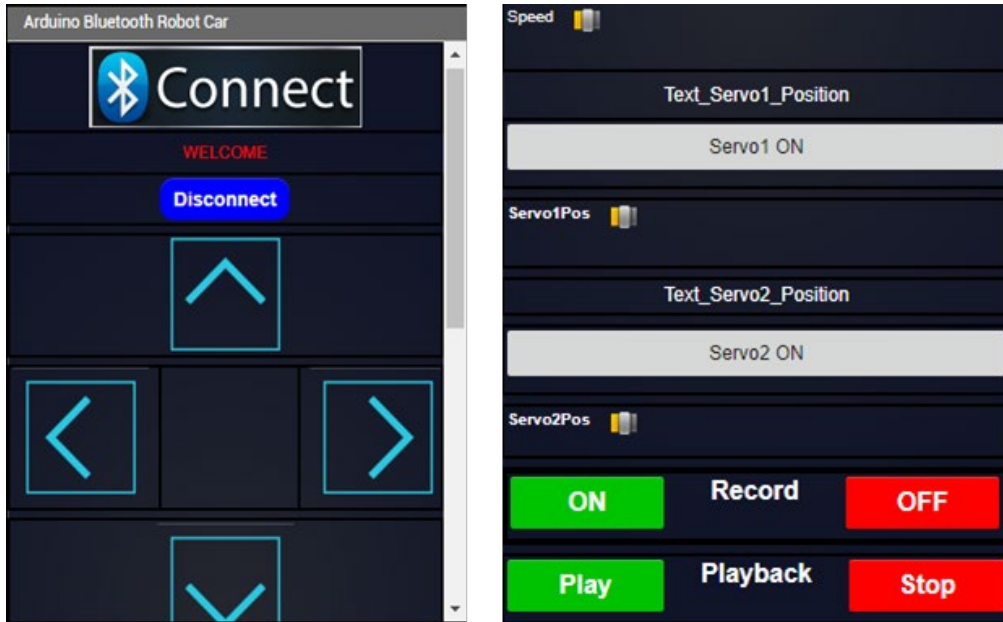
The hardware involved is as follows:

1. **Arduino Uno:** This is the primary of two Arduinos. It is the main control unit of all the system components. The secondary Arduino Uno is dedicated to the video camera.
2. **Arduino L298 Motor Driver Shield:** The motor shield receives signals from the primary Arduino Uno and provides power to drive the four DC motors, which form the motion base of the robotic model.
3. **HC-05 Bluetooth module:** The Bluetooth device used in this project is the HC-05 Bluetooth module, which is a short-range device used for bidirectional data transfer. The frequency at which the device operates is 2.4 GHz (Cotta et al., 2016; Piyare & Tazil, 2011).
4. **Servo Motors:** The system consists of a two-degree-of-freedom robotic arm, which is designed using two servomotors, one for each action. This robotic arm is intended to act as a nut delivery system to provide treats to the animals. The larger, 180-degree servo is used to move the treat towards the animal while a smaller, 90-degree servo is used to release the treat.
5. **ArduCAM ESP8266 Arduino Uno Wi-Fi board and 2MP ArduCAM Camera Module:** The video system includes a 2MP (two megapixel) ArduCAM mini camera module, which supports live video streaming from robot to laptop.
6. **ISD 1820 Voice Recorder module:** The audio system includes an ISD1820 Voice Recorder module, which supports voice recordings and playback.
7. A single 9.6V 2000 MAh (2000 milliamp hour) battery provides sufficient power to drive the entire robotic system. Other voltages were produced with voltage regulators.

Operating the robot is accomplished via a smart phone with a customized app (MIT App Inventor). Figure 4 provides an overview of the app. The commands are conveyed from the smart phone to the robot via Bluetooth. The signal is received on the robot with the Bluetooth module, and sent to the primary Arduino Uno. This Arduino decodes the commands and performs the needed functions. One of the functions is to give the motor shield drive commands to move the motors. Other functions operate the Audio record/playback system and the two servos. The secondary Arduino Uno, in conjunction with a Wi-Fi module and camera, streams the video to the laptop.

Figure 4

Overview of the Smart Phone App



Communication System

The communication between the robot and the smart phone is achieved with the help of an HC-05 Bluetooth module. This Bluetooth module acts as a medium through which data transmitted from the smart phone is received on board the robot.

A unique and an effective single-byte, single-command communication system has been devised. This method allows the conveyance of multiple commands and operations required to control the Squirrel Robot system, within the limit of one byte (8 bits). The communication between the smart phone and the robot is through an 8-bit message, which represents a set of 256 values.

The command format is coded in a single 8-bit byte. There are 12 different functions; 9 are single valued, 3 are multivalued. The decimal representation of this byte refers to a single command. If the 8-bit byte is the binary code 0000 0001, then it corresponds to the decimal 1 and commands the robot to move forward.

The same holds true for decimal codes 2 through 9.

For the multivalued commands, in the case of speed control of the motors, the values 10 to 200 correspond respectively to 0% to 100% Pulse Width Modulation (PWM) (Patel et al., 2017). For example, 105 corresponds to 50% PWM which would drive the motors at half speed.

Servo 1 movement commands 201 to 229 correspond to 0 degree deflection to 180 degree deflection with a resolution of 6.2 degrees.

Similarly, Servo 2 movement commands 230 to 255 correspond to 0 degree to 90 degree deflection with a resolution of 3.5 degrees.

Table 1*The 12 Different Commands*

Commands	
Forward	1
Reverse	2
Rotate right	3
Rotate left	4
Stop	5
Start recording	6
Stop recording	7
Start playback	8
Stop playback	9
Speed control of the motors	10 to 200
Servo 1 movement	201 to 229
Servo 2 movement	230 to 255 Android Application.

There are many controls on the Android application, which enable the above-mentioned 12 operations, shown in Table 1. These operations are wirelessly conveyed to the robotic model. The app has 10 buttons for Bluetooth connectivity, direction control, and audio system. It also has three sliders: One supports motor speed control, and the other two are used for servomotors angular control to operate the robotic arm. After communications between the smart phone and the HC-05 Bluetooth module (on the robot) are established, the buttons and the slider controls can be activated to operate the robot. See Appendix A for the Android App code.

Arduino Code

The Arduino code communicates with the Bluetooth module, connected to the Arduino. The Arduino in turn decodes the received code and performs the corresponding operation. The required programming is performed using the Arduino IDE software. See Appendix B for the Arduino code.

Video of Robot in Operation

Supplementary files shows a brief video clip of the robot being remotely operated. This video clip demonstrates the treat-delivery system. The nut is manually loaded onto the robot, and the robot is remotely driven to the subject, where the robotic arm delivers the treat. The arm is then retracted, and robot is guided back to the operator. The robot has many other capabilities such as video, sound, and other unique qualities as mentioned throughout the paper.

ArduCAM

Appendix C shows the code necessary to stream the video from the robot to the laptop.

Potential Experiments

There are many experiments students can do with their robot. As in many instances, the type and range of the experiments are only limited by the student's and professor's imagination. Tables 2 and 3 list some suggested discussion questions and experiments.

Table 2*Class Discussion Questions*

Example Discussion Questions
Why is the study of robotics of interest to comparative psychology?
What other fields in behavioral science make use of robots?
How are robots being used in other sciences interested in behavior?
What are some examples of robotic animals?
What features should be included when designing your robot?
What are the advantages and disadvantages of constructing your own robot rather than modifying a prefabricated robot?
What observations can be made with a robotic animal?
What experiments can be done with a robotic animal?

Note. This table provides sample questions to help aid in-class discussion. These questions are helpful to implement to help keep the class discussion focused on the activity.

Table 3*Observations, Experiments, and Topics for Discussion*

Observations/Experiments/Topics
How close can the robot approach the target animal before the robot is noticed?
Describe the behaviors of the target animal in relationship to the robot.
Design a habituation experiment to decrease reactions of the target animal to the robot.
Is the proximity of the robot to the target animal affected by the appearance of the robot?
In a social situation, can the robot be accepted within the group?
Does the delivery of rewards make the robot more acceptable to the target animal?

Note. This table provides sample questions and statements to aid in deeper understanding.

Discussion

As the past decade has produced an explosion of studies using robots for behavioral research (Romano et al., 2019), the main objective of this paper is to suggest that robotics be incorporated into comparative psychology courses. This project can be assigned as a class project, independent project, or directed study. Students can work in groups or on their own. Moreover, a new course, “Robotics for psychologists,” can be developed that solely focuses on robotics and psychology. The robot project can also be used as a Master’s project.

When designing the robot, students should consider the purpose of the robot, what features it should possess, and cost. In our design, we wanted to start from scratch, although commercially available robots can

be modified. If a prefabricated robot is used, perhaps the simplest modification is to attach a plastic or cardboard representation on top of the robot. The robot project also encourages interactions between comparative psychologists and engineers and between psychology students and university/college robotics clubs.

The rationale behind designing a robot from scratch is five-fold. First, no commercially available robot is going to have all the features necessary for a specific application. For example, our squirrel has the ability to record and playback sounds and administer rewards. Second, it sharpens a student's observation skills as it will require the student to consider how the sensory and response systems of their target organism should be integrated into their robot. Third, it will teach comparative psychology students useful skills such as programming and logic. Fourth, students will develop problem solving skills as they overcome design challenges. Fifth, the robot is less expensive.

Our goal was to build a low-cost, remote-controlled robot that would allow the study of squirrels in the wild. The robot was intended to possess capabilities, such as remote control, the ability to record and playback sounds, stream live video, and have an operational robot arm that acts as a nut-delivery system. In addition to this, the major objective was to design a low-cost robotic model for less than \$200. The robot that was constructed met all the desired specifications. Supplementary files provides video examples that show the operation of the robot and some of its features, including operation of the robotic arm and control of the robot by phone.

Bluetooth technology was chosen over the Mercury Remote Robot Challenge communication system because of lower cost and simplicity. If needed, a longer range communication system could also be employed in future robots. In this project, a unique yet simple and effective means of operating the robot was devised. This method required only a single byte to convey all the information necessary to control the Squirrel Robot system.

The robot could include more capabilities such as a complex robotic arm and structure. A longer range communication system could also be employed. With Bluetooth, the robot can be controlled remotely for approximately 100 ft (30.5 m). If the robot needs to be controlled from a long range (i.e., from one nation to another), a different remote control system is needed. In this case, a communications technique, such as those used in the Mercury Remote Robot Challenge, would need to be employed. This long-range communication would allow a researcher in one country to operate the robot located in another country. This very long range communications system, however, was not part of this effort.

Since this project did not have any time-based critical functions to perform, a single function operation system was adequate for our needs. If additional functionality is required, a more sophisticated communication system could be developed to permit multiple functions to perform simultaneously. This effort was designed to work with Android phones, but it can be implemented with iOS phones, too. This project was designed to study squirrels, but our strategy could be modified for other animals, including aquatic animals, dogs, cats, and, if drones are used, birds.

We would like to mention one limitation. When the project was designed, Oklahoma State University was home to many squirrels. They were found all over campus, as well as in parks associated with Stillwater, Oklahoma, USA (the location of the main campus). The large number of squirrels was the reason why we decided to focus on squirrels. However, at the time of testing, the squirrels have all but disappeared. One possible explanation for this phenomena is that the campus shutdown necessitated by COVID-19 reduced the number of people on campus who would feed the squirrels. Thus, we could not test how our robotic squirrel would interact with live squirrels.

An issue that may dissuade some professors from using robots is unfamiliarity. We do not view this as a problem because students (and colleagues) at many levels of the educational system (including elementary school) are already using robots in their classes (Druin & Hendler, 2000). By the time they reach university, these students will already have the necessary experience in using robots. Moreover, most university/colleges

have robotic clubs, and these clubs can serve as a resource.

In closing, we would like to stress that the robotic project represents a continuation of our efforts to enhance the visibility and viability of comparative psychology. Our laboratory has gone about this several ways. These include writing articles highlighting the importance of comparative psychology to Asia and Africa (Abramson & Kitching, 2018; Abramson & Radi, 2019; Stauch et al., 2019), developing low-cost experimental controllers suitable for both the field and classroom (Varnon & Abramson, 2013, 2018), editing a special issue highlighting the importance of comparative psychology (Abramson, 2018; Abramson & Hill, 2018), and discussing the importance of philosophy to comparative psychology (Brown & Abramson, 2019). Moreover, our laboratory has developed many hands-on, inquiry-based learning activities for students (Abramson, Curb, et al., 2011; Abramson, Hilker, et al., 2011; Bergren et al., 2019).

Given student interest in robotics (Panayiotou & Eteokleous, 2017), we believe that this article can not only help with comparative research but also in the recruitment of students (Abramson, 2015a,b). The development of low-cost robotic animals represents another attempt to encourage students to enter this vibrant and relevant field of enquiry.

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