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Instrumental Reinforcement and Thermoregulation in the Domestic Chick: An Inquiry Based Learning Project

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As science has become widely recognized as both process and product, educators in scientific and related fields have moved toward inquiry-based student centered learning as a preferred pedagogical approach. This trend is supported by evidence of its positive effects on students and student outcomes. In order to evaluate the effectiveness of cooperative, inquiry based instruction for advanced undergraduate students we piloted a project using thermoregulation in the domestic chick. Our goal was to immerse students in an experimental behavioral research project from start to finish. Our emphasis was on (1) research as a process (i.e., the importance of scientific rationale, design, method, data collection and analysis); (2) ethics of behavioral research; (3) application of basic principles of learning – specifically reinforcement. We were required to work within the constraints of a small budget and we wanted the project to be flexible enough to be used in different ways to expose students to the science of learning. The project described in this paper is inexpensive and relatively easy to construct, design and conduct. It is also ideal for students who have had no, or little, experience working with laboratory animals. Finally, it is flexible allowing one to use and adapt it for different purposes.

Keywords: *Instrumental reinforcement, thermoregulation, domestic chick, inquiry based learning*

Inquiry Based Education

Pioneers such as Thomas Huxley, Herbert Spencer, Charles Eliot, and John Dewey helped to highlight the value of inquiry-based education (Deboer, 2004). Education in science, math, engineering, and technology has moved toward inquiry-based student-centered learning as the preferred method of instruction as science has become recognized widely as both process and product (Deboer, 2004; Smith, 2008). A 1996 report to the National Science Foundation titled *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* set the goal that all students would learn these subjects through direct experiences (Smith, 2008). In 2000 a survey of over 70 members of faculty indicated that many teaching biology, physics, or chemistry classes were using student-centered inquiry as a pedagogical tool (Smith, 2008). This trend is not surprising, considering that inquiry based learning is known to support understanding of both the scientific method and its content (Deboer, 2004).

The most obvious purpose of inquiry based learning approaches is the preparation of future scientists. However, such methods are also valuable to students who do not plan a career in science by preparing them to become independent and critical thinkers who can evaluate information effectively (Deboer, 2004). Research also indicates that cooperative learning, which is a component of many inquiry based methods, leads to better outcomes for students than competitive or individualistic methods (Smith, 2008). The advantages of cooperative learning include higher achievement and productivity, strengthening of relationships, and improved self-efficacy (Cooper & Robinson, 2000). The strengthening of relationships is particularly important because research has shown that peer relationships are a factor associated with college success. It is particularly important for students to build strong peer relationships, as failure to do so has been reported as a major issue in some students' decision to drop out of college (Tinto, 1994).

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Thermoregulation: A Model for Teaching Basic Principles of Behavior

In order to evaluate the effectiveness of cooperative, inquiry based learning for advanced undergraduate psychology, neuroscience, and pre-medicine majors, we conducted a project using thermoregulation as a model behavior that could be studied easily and economically. The project was developed as a laboratory exercise to be used in the learning processes course taught in the psychology department at Arkansas State University. Learning Processes is an advanced level undergraduate course that currently services approximately 40 students each fall semester. This course comprises primarily psychology majors; however, students interested in applying to medical school and neuroscience graduate programs also enroll. Demand for the course is on the rise as it is one of the few undergraduate courses with an emphasis on non-human methods. We agree with the view that the decline in student exposure to, and training in, the use of laboratory animals is problematic for neuroscience, pre-medicine and psychology majors (Pearce, Biondolillo, Srivatsan, 2010). Additionally, large class size makes it difficult to provide hands-on experiences for students in many undergraduate programs. However, given the limited access undergraduates have to non-human subjects, we view the learning processes course as an important and appropriate place to provide meaningful hands-on opportunities when possible. We recruited a small group of highly motivated pre-medicine and psychology majors to participate in the project. The students selected for the pilot project reported a strong interest in developing skills in experimental behavioral research and each committed to seeing the project through to completion. The first author was familiar with each student and was confident in their ability to complete the project. Their assignment was to design a set of procedures that would allow temperature to be used to control a basic instrumental response in the domestic chick.

Thermoregulatory mechanisms, both physiological and behavioral, are those mechanisms employed by organisms to keep their body temperature within a certain range, even when the surrounding temperature deviates from this optimal range. These mechanisms have been documented in mammals, reptiles and birds (Du et al., 2011; Luskik et al., 1978; Maloney & Dawson, 1994; Seebacher & Franklin, 2007; Terrien et al., 2011). Given the focus of the learning processes course, our interest was in the overt responses that non-humans exhibit to achieve thermoregulation, as these can be used to demonstrate basic principles of learning. There is an established experimental literature linking instrumental behavior and thermoregulation. Rats placed in a room held at 2°C have been shown to engage in a high rate of lever pressing in order to receive a 10-s heat reinforcer (Carlton & Marks, 1958). Contingencies in which lever pressing controls the ambient temperature inside an operant chamber, via the flow of hot water and cold water through tubes surrounding the chamber, resulted in rats responding to both levers in a way that kept the chamber within a range of 5°C or less (Wright & Meyer, 1969). Similarly, contingencies in which shuttling controlled the activation of cold air in a high ambient temperature condition or the activation of warm air in a low ambient temperature condition resulted in rats shuttling in both ambient temperature conditions in a manner that resulted in the maintenance of stable body temperatures (Chen et al., 1998). Chen et al. (1998) noted that the rats' performance was stable by the third session and argued that rats learn to shuttle for a thermal reinforcer more readily than they learn to press a lever for the same stimulus consequence. Thermoregulatory behavior in the chicken has also been examined.

Adult chickens demonstrate clear species-specific behavior (e.g. feather fluffing) and autonomic responses (e.g. shivering) to regulate and compensate for cold ambient temperatures as low as -5°C (Horowitz et al., 1978). The thermoneutral temperature zone (TTZ) is the range of ambient temperatures at which an organism's metabolic processes do not change to maintain optimal core body temperature. Young chickens (day 0-day 7) have a narrow TTZ of 33-35°C (Moraes et al., 2002). By one week of age, chicks have the ability to regulate their rectal and surface body temperatures through internal physiological mechanisms (Lin et al., 2005). Our anecdotal observations indicate that young chicks, hatched and brooded artificially in an open brooder, respond quickly to minor fluctuations in ambient temperature. Open brooders are designed to allow chicks to freely move about in a space containing all necessary resources for survival, health and growth. Brooder sizes vary depending on husbandry preferences, but successful open brooding demands that chicks have access to a heat source, typically a heat lamp suspended above the brooder. This allows for natural temperature differences within the brooding arena. Chicks approach/escape the heat source in response to changes in external temperature. For example, chicks will congregate under the heat lamp when the ambient temperature drops and will disperse to points distal to the heat

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lamp when ambient temperature rises. Developmental changes also contribute to the frequency with which chicks approach a direct heat source. Poultry breeders follow the general rule of thumb that chicks between hatch and post-hatch day 7 should be maintained at an ideal temperature of 95° F when being artificially brooded. The ideal temperature for artificial brooding is reduced by 5° F for every 7 days of post hatch development.

Domestic Chicks as a Training Subject

While less behavioral research has been done with the chick than other species, we chose it as our subject for practical as well as methodological reasons. The established knowledge base surrounding thermoregulation and successful poultry husbandry, taken together, allowed us to establish procedures that would be both appropriate and attractive for a group of advanced undergraduate students tasked with developing a research project, based on an established animal model, to illustrate the function of instrumental reinforcement. Chicks exhibit easily defined and measured instrumental approach (and escape) of a heat source to regulate temperature. They are economical to obtain, relatively easy and inexpensive to maintain ethically, and require minimal training for handling. Most undergraduate students have had little or no formal experience with laboratory animals and a typical undergraduate student tends to find chicks "more approachable" than rats. Evidence shows that many students are hesitant to enroll in courses involving animals, despite the fact that the same students often judge the experience as being worthwhile after having had it (Plous, 1996). These findings are supported by the personal experience of one author who often relies on the use of rats in a teaching laboratory taught in conjunction with another course. In addition, because young chicks' optimal ambient temperature consists of a relatively narrow range we expected it would be easier to motivate an instrumental response in chicks versus rodents using relatively basic technology and procedures.

Our subjects were 25 domestic chicks from available 1-day old heavy laying breeds that were selected randomly by Murray McMurray hatcheries (Webster City, IA). We used only females to ensure we could place them easily upon completion of the study. Arkansas State University is located in the city of Jonesboro; however, the landscape beyond Jonesboro is rural and agricultural. Our young healthy pullets were readily adopted by local individuals who maintain chickens for purposes of egg production (including the senior author). Chicks were housed communally in 61cm (l) x 30.5cm (w) x 45.7cm (h) cm brooding boxes constructed in-house from materials readily available at any major hardware store. We followed an easy design outlined at http://www.poultryhelp.com, but there are many other easy-to-make and commercial brooder options available.[1]

Apparatus and Procedures

The apparatus consisted of an in-house constructed shuttle box which measured 91.44cm (l) x 25.40cm (w) x 30.80cm (h). The box was made of wood with one half of the interior painted white and the other half painted black to ensure students could clearly and consistently score shuttle responses. Heat lamps (250 w red Satco) were secured at both ends of the shuttle box using clamp lamp fixtures with heavy aluminum shades. Students controlled the heat lamps manually via a power strip with an on/off switch. Students arranged two response-consequence contingencies: shuttle to activate the heat lamp and shuttle to deactivate the heat lamp. While manual control of the lamps has disadvantages such as increased variability and the necessity for manual data recording, this approach offers a number of advantages. The cost to construct the apparatus is kept low since it does not need expensive transfer detection sensors or a computer. The apparatus requires minimal space and upkeep as there is no equipment to malfunction. More importantly, manual control of reinforcer delivery requires students to devote their full attention to the experiment. It gives students a very "hands-on" role in both shaping and observing behavioral changes that occur in the subjects. Overall, this approach results in students being completely engaged in the formation of operational definitions, data collection, and observation of behaviors that occur within the apparatus across trials and sessions. Experimental error can be treated as secondary (we chose to approach it in this manner for this project) or it can become a focal issue depending on the goals of the exercise as determined by the class instructor.

Same sex chicks were housed in groups of 6-7 with free food and water and a local, controlled temperature (within brooding box) of approximately 95° F during post-hatch days 1-7; 90° F for post-hatch days 8-14; 85° F for post-hatch days 15-21. Brooders were illuminated and heated using heat lamps secured in clamp light fixtures with aluminum shades suspended from above. The floor of each brooding box was covered with paper towels for the

[1]http://www.grit.com/Chickens/Make-a-Chicken-Brooder-Out-of-Cardboard-Boxes.aspx; http://www.poultrymansupply.com/2007Brooders.htm; www.mcmurrayhatchery.com.

first week and newspaper and a layer of shredded pine bedding thereafter. Bedding was changed daily. Water and food (Purina chick starter crumbles) were provided using standard farm feeders and waterers which were cleaned and filled daily when bedding was changed. Brooders were thoroughly cleaned as needed (every 5-7 days) with Tek Trol disinfectant solution. Subjects were monitored daily to confirm adequate consumption of food and water.

During experimental sessions chicks were placed in pairs in one side of the shuttle box which was housed in an experimental room with the ambient temperature at approximately 68-72° F. Chicks were run in pairs to reduce stress related to isolation, a decision that was made by the students. A series of experimental trials were conducted with the following components of each trial. Chicks were placed in one side of the shuttle box and the local temperature of that side of the shuttle box was manipulated to arrange one of two contexts which served as the antecedent condition for two contingencies: (1) a local temperature below ideal by 5-10° on the F scale (e.g., 80-90°F during first 7 days post-hatch); and (2) a local temperature above ideal by 5-10° on the F scale (e.g., 100-110°F during first 7 days post-hatch). The temperature was manipulated through the manual activation and deactivation of the heat lamps. Real-time temperature monitoring was made possible through the use of an instant read infrared thermometer. Under both context conditions, shuttling to the other side of the apparatus resulted in the temperature coming closer to ideal (e.g., 95°F) for an established inter-trial interval (ITI) which was arbitrarily determined as 30 s as we found no previous data to indicate effective ITI durations. Chicks were exposed to no more than 10 such trials during experimental sessions. Chicks were run in one experimental session per day. At the end of a session, chicks were returned directly to their home brooder which was maintained at the ideal temperature for that developmental period.

Student Responsibilities

Students were an integral part of the research team and were responsible for all phases of the study from design to data analysis. Prior to running the study, we met with students regularly to discuss the purpose of the experiment, the experimental design, and the procedures to be used. All students received basic animal handling and maintenance training provided by the senior author and they were required to complete basic IACUC training through the CITI program under the supervision of the senior author. They also contributed to the writing and submission of the IACUC protocol. Upon finalizing the design, the students divided themselves into two teams of 3 students and each team was responsible for running half of the subjects. The senior investigators encouraged the students to work together to determine a schedule that would allow them to run the experiment 7 days a week. The students successfully established this schedule and no experimental sessions were missed during a three week period. Students were encouraged to communicate both within and between groups to ensure that the subjects were properly maintained and sessions were being conducted according to defined procedures. In addition, the groups were encouraged to contact the lead investigators with progress reports, and as any problems arose. The faculty advisors attended several experimental sessions on a quasi-random basis, but largely allowed the student groups to work autonomously. Students agreed that latency to shuttle would serve as the dependent variable for the study.

During the study, the students noted that a large degree of variability existed between subjects. Some subjects learned to shuttle for positive and/or negative reinforcement, some persisted in trying to escape from the apparatus, and some showed evidence of stress and emitted distress calls. While such variability is often seen as a hurdle to overcome, we feel that this variability is a crucial part of the learning experience for undergraduate students conducting one of their first experiments. Further, it provided excellent empirical fodder for discussions of adaptations that have emerged from phylogenetic pressure as well as focal ontogenetic adaptations of both non-associative and associative nature. Part of the learning experience for the students was the discussion of ways to modify the procedure that might result in less variability and greater validity. However, our goal was not to design and conduct the perfect study for which undergraduates would collect data, but rather to allow a group of students to directly gain the entire research experience within the context of an established knowledge base relevant to the science of learning.

Closing Remarks

The project was viewed as an overall success by faculty advisors and student researchers. At the conclusion of data collection, students could communicate a clear understanding of basic research design issues, ethical considerations involved in working with live subjects, and of the processes of positive and negative reinforcement. They felt the project to be a worthwhile and challenging application of their research and learning science skills and all reported having enjoyed working with the subjects. Students are currently working on data analysis and designing a follow-up study. The project, as we designed it, required considerable student investment out of class especially during the knowledge gathering and design stages. Data collection itself can be completed within two to three weeks. Thus, the time commitment could be attenuated by reducing the research design requirements for students and instead creating basic instructor led illustrations or learning modules using the same basic procedures and apparatus.

Our approach was decidedly low-tech in terms of the apparatus and data collection procedures used. For situations requiring a more technologically advanced approach, this method would not be suitable. However, one could clearly design this study with more advanced technologies, such as that described by Chen et al., (1988) if that is financially feasible or of interest to the instructor of the course. Although some may view the low tech approach as a weakness, we view it as one of the major strengths of the exercise. We operate with a minimal budget as do many small underfunded programs and we have full teaching loads. Chicks are relatively inexpensive to purchase and house. Very little financial investment was needed for construction and maintenance of the shuttle box. In addition to being cost effective, the project demanded very little space and minimal training and direct supervision for students to use. Students felt confident and comfortable working independently with both subjects and apparatus. Further, and importantly, the approach we used set the occasion for full student engagement in the behavioral observation procedures. We are confident that this approach was more effective in illustrating reinforcement in action than the automated approach would have been.

One of the roadblocks to using non-human laboratory exercises in the undergraduate classroom has become the global concern for the humane and ethical treatment of animals. Because our procedures use the domestic chick, are non-invasive, involve no pain, and are minimally stressful to the subjects, we readily obtained Institutional Animal Care and Use Committee (IACUC) approval to conduct the study. In addition, the project lends itself to engagement of students in the preparation of the required protocol documents and encourages students to develop a more nuanced appreciation for the role of the IACUC. We directly involved students in the process to ensure they were fully invested in the ethical issues surrounding the use of live subjects. Finally, it is much easier, and viewed as more appropriate, to establish an adoption program for young pullets than it is for the standard laboratory rat, which removes issues of euthanasia at the end of the study.

One of the most promising indications that the project was a success came in the form of a proposal, driven by the students who had participated, for a follow up study to be conducted. We are currently engaged in discussions of procedural modifications that will improve the basic methods used in the first study.

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