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# A Sample of *CyberRat* and Other Experiments: Their Pedagogical Functions in a Learning Course

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This paper describes an integrated series of assignments and participatory exercises based on in-class workshops and software-based simulations that supplement live animal laboratory experiments in a Learning-with-laboratory course at Rollins College. Our Learning course is taught in a behavior-analytic tradition, uses Catania's *Learning* (2007) textbook, and draws pedagogical inspiration from early courses offered at Columbia (Keller & Schoenfeld, 1949) and at Harvard (Skinner, 2003) that relied heavily on laboratory exercises and/or programmed instruction. It strives to give students direct experiences with how the behavioral principles being taught apply to their own education. The exercises we report here are only a subset of those used throughout the course and are selected to illustrate especially how *CyberRat* (Ray, 2003) can be used to generate data to demonstrate outcomes from each procedure described by Catania's taxonomy of experimental operations (e.g., Catania's Table 2-1, p. 27, also reproduced as our Table 1). His experimental operations and their related behavioral phenomena include: 1) observation operations and behavioral hierarchies, 2) stimulus presentation operations and elicitation, 3) signaling stimulus presentation operations and respondent conditioning, 4) consequential operations and operant conditioning, 5) signaling consequential operations and stimulus discrimination, and 6) establishing operations and motivation. We also describe how we teach applications of the behavioral principles covered in the course, including a collaboratively developed contracted learning experience that is introduced around mid-semester (Ray & Salomon, 1996).

Keywords: *CyberRat, experimental activities, software-based simulations, behavior analytic, experimental operations, applied behavioral principles, contracted learning*

In the late 1940s and early 1950s there were pedagogically revolutionary efforts made to modify both the content and the process used to introduce university students to psychology. Of particular note was Keller and Schoenfeld's (1949) innovative two-semester course at Columbia. This course integrated animal and human laboratory exercises with lecture-delivered content that evolved into a landmark textbook (Keller & Schoenfeld, 1950) that is still available today.

The Columbia course was designed to be "biologically toned, experimentally grounded, and systematically presented" (Keller & Schoenfeld, 1949, p. 166). The course also set out to redefine what an introductory experience should be for students (e.g., Dinsmoor, 1989). Rather than presenting a disjointed overview of all the topics investigated by psychologists, the course focused on integrating and applying a specific experimental, or behavior analytic, perspective. Both the course and the subsequent textbook it inspired were designed with the following goals and objectives: 1) to educate students regarding the principles Skinner (1938) articulated in his *Behavior of Organisms*; 2) to present an integrated model of psychology; 3) to expose students to scientific methodology; 4) to present real-world applications of the behavioral principles being taught; and 5) to foster enthusiasm for the field (Keller & Schoenfeld, 1949).

But quite beyond the landmark content, the Columbia course was especially noteworthy for its incorporation of weekly laboratory meetings where students actively engaged in conducting experiments and collecting data. Keller and Schoenfeld's heavy emphasis on the use of animal as well as human experimentation as an integral part of this course was driven by strong pedagogical philosophies. They state, "We are convinced that such participation in the business of science makes for better education, whether as background for a liberal arts student, or special training for the one who plans a scientific career" (Keller & Schoenfeld, 1949, p. 169).

Meanwhile, B. F. Skinner was offering his own groundbreaking course at Harvard University: *Natural Sciences 114,* (Skinner, 2003). In his course, Skinner was experimenting with simplifying and applying his earlier work to make it more palatable for the general student audience—an effort that resulted in the publication of Skinner's (1953) *Science and Human Behavior*. In addition, he subsequently integrated his radically new pedagogical technology he called "programmed instruction." Eventually, a programmed instructional presentation of the text for his Harvard course in Learning became a separate publication called *The Analysis of Behavior* (Holland & Skinner, 1961).

More than a half-century has now passed, and one might well ask what form such a course might take in today's educational environment? We offer a series of concrete examples to illustrate how a modern course incorporates programmed instruction and direct student experiences of applied behavioral principles. In addition, we summarize a set of illustrative classroom and laboratory exercises—both human and non-human—that serve much of the function of the original Columbia series, though they take a different form. Thus the course we describe remains steeped in the historical tradition and spirit of those offered by Keller, Schoenfeld, and Skinner.

Of course we have adopted an updated text that integrates modern research (Catania, 2007), but one that is also true to the tradition of Keller and Schoenfeld (1950). Likewise, the course we describe incorporates modern innovations in digital technologies along with more traditional human and live rodent laboratory experiments. These new technologies are especially significant in that they make it easy to individualize the pacing of the course if one chooses to do so—a topic also dear to Fred Keller's heart, and one he emphasized in his acclaimed Personalized Systems of Instruction (cf. Keller, 1968). Such technologies also accommodate distance-delivery of the course's content and activities, should that be desired. Importantly these modern technologies continue to reflect a confidence in appropriately applied programmed, albeit adaptive, instructional reading supplements and mastery-focused certification testing, as well as in student-generated data derived from direct and personal experimentation.

## The Learning with Laboratory Course

The course we describe in this paper is *Psychology 341- Learning with Lab*, a junior level course that includes two weekly laboratory meetings that are 75 minutes in duration. For many years the Learning course has been a core requirement for all psychology majors at Rollins College. Catania's (2007) text, *Learning*, has been the required textbook in this course through several editions. While not the primary reason for adopting this text, Catania happens to be quite logically positioned to carry on the tradition first established by Keller and Schoenfeld's (1950) *Principles.* As a student at Columbia University, Catania was enrolled in that undergraduate introductory sequence offered by Keller and Schoenfeld, and he subsequently obtained his PhD working with B. F. Skinner at Harvard. It is not surprising then that Catania's textbook shares many of the initial goals established in Keller and Schoenfeld's original book, including an integration of a diverse literature from both behavioral and non-behavioral perspectives into a text that is, nevertheless, decidedly behavior analytic in orientation.

As illustrated in Table 1, Catania (2007) organizes his text around a series of key experimental procedures, or "operations" performed by researchers (cf. Skinner, 1938; Verplanck, 1957 & 1996). The exercises we detail in this article are focused on illustrating each of those operations, although instructors using alternative textbooks or approaches could just as easily focus on the behavioral principles and outcomes the exercises illustrate instead of the operations performed. Unfortunately, many undergraduates find Catania's writing style less accessible than Keller and Schoenfeld's. We thus supplement Catania's text with an online set of adaptive instructional tutorials (Ray, Belden, & Eckerman, 2005) that offer both a supplemental overview as well as detailed discussions of concrete applied examples of the behavioral principles described by Catania. And following Keller and Schoenfeld's (1949) emphasis on the value of live animal and human laboratory exercises as an integral part of their course, we also incorporate an integrated series of experiments with both laboratory rats and computer-based simulations that students conduct and either present orally in mock conference style or as written APA styled experimental reports.

Our course's sequence of exercises reflects many of the same behavioral principles incorporated into the original Columbia series. Also, in the spirit of the Columbia course's use of its students as participants in many of their own experiments, our

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Table 1. Catania's (2007, p. 27) Table 2-1 illustrating his "Basic Behavioral Operations."

| Operation | Description | Examples | Usage |
|---|---|---|---|
| **1. Observation** | No Intervention. | We watch an animal behaving. | ----- |
| **2. Stimulus-presentation operation** | Stimulus A is presented. | *Loud noise* (A) startles child. Physician shines *light* (A) in patient's eye. | Stimulus *elicits* response; response is *elicited by* stimulus. |
| **3. Consequential operation** | Response B has consequence C (e.g., a stimulus is produced or terminated). | *Putting coin in vending machine* (B) produces *soft drink* (C). *Touching hot stove* (B) produces *burn* (C). *Light goes out* (C) when *switch is thrown* (B). | Response is *emitted.* |
| **4. Signaling or stimulus-control operation: Superimposed on stimulus presentation** | Stimulus D signals presentation of stimulus E. | *Lighting* (D) precedes *thunder* (E). | Stimulus *elicits* response; response *is elicited* by stimulus. |
| **5. Signaling or stimulus-control operation: Superimposed on consequences** | Stimulus F signals response G will have consequence H. | *Red traffic light* (F) signals that *driving through intersection* (G) may lead to *traffic ticket* (H). *Ringing telephone* (F) signals that *answering* (G) may provide *opportunity for conversation* (H). | Stimulus *occasions* response; response *is emitted* in presence of stimulus. |
| **6. Establishing operation** | Effectiveness of consequence I as a reinforcer or punisher is established. | *Food* (I) becomes an effective reinforcer after food deprivation. The presentation of shock makes *shock removal* (I) a reinforcer. When it is important to unlock a door, *the key to the door* (I) becomes a reinforcer. | An event is *established* as a reinforcer or punisher. Behavior is *evoked* by the establishing operation. |

course also utilizes its students as participants in experiments that begin with the very first day of the course. The course also uses software-based exercises designed to remind students of their previously studied descriptive and experimental research methods and data analyses covered in prerequisite courses. The new behavioral principles taught in the course are also thoroughly illustrated by assigned human and animal experiments and applications. We emphasize again, however, that any or all of the laboratory activities to be described could easily be conducted in isolation and without reference to this course's structure or textbook adoption.

Several software packages have been designed for use in this course, and are available as commercial products. But all have free non-data-saving "visitor" versions and free accompanying pdf-formatted *User Guides* and/or content documentation that is downloadable from a web site at http://www.ai2inc.com. Only a few of these packages will be described in this article. The primary software to be detailed presently is *CyberRat* (Ray, 2003; www.CyberRat.net). It serves as a functional supplement and/or total replacement for various live animal laboratory exercises using rats. Throughout our own course, *CyberRat's* experimental simulations are used to extend the live animal experiments conducted within fixed-duration laboratory periods and, thus, offer supplements that allow students to conduct additional experiments outside of scheduled class and laboratory periods. These assignments extend the breadth and sophistication of possible experiments and, unlike live animal experiments, can be completed easily within the limited time span of a single semester.

*CyberRat* is a simulation software system based on a corpus of over 1800 digital video clips of live animals and is designed to faithfully reproduce a wide range of operant conditioning fundamentals. The parametrics modeled are highly realistic and include reproductions of early session warm-up durations that precede bar pressing, true rates of satiation to various schedules of water reinforcement, realistic patterns of extinction, spontaneous recovery,

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ratio-strain dynamics in reinforcement schedule transitions, stimulus discrimination development, and many more. Original live animal research was used to establish the validity and reliability of parametric outputs for nearly all available exercises and/or experiments in *CyberRat*, as has been detailed elsewhere (Ray, 2011; Ray & Miraglia, 2011).

A second software package we use is designed for computer-based adaptive programmed instruction. This package offers internet-delivered instructional tutorials (Ray et al., 2005; www.ai2inc.com/Products/CR_Tutor.html) that were designed to be a supplement to *CyberRat*. Thus many of its descriptions of principles, such as response shaping via successive approximation techniques and effects of various intermittent schedules of reinforcement, use *CyberRat* as a direct reference. These tutorials not only cover the foundational concepts of learning and conditioning but also are designed to offer numerous illustrations of behavioral applications, including programmed instructional design. Having detailed some of the specific software used in the course, let us now focus our discussion especially on *CyberRat* assignments and their pedagogical functions.

## Samples of Class and Lab Experiments

### Observation Operations and the Impact of Establishing Operations

We begin with reading assignments, both in Catania (2007) and the *Learning and Conditioning Tutorials* (Ray et al., 2005), to acquaint students with the similarities of, and differences between, adaptations in phylogeny (evolution) and in ontogeny (learning). In class we begin the course on the very first day by exploring the concept of behavioral observation. Behavioral observation is the simplest of Catania's behavioral operations as described in Table 1. What differentiates observation operations from their more complex counterparts is the lack of any manipulative or environmental intervention. However, as simple as this operation appears to be when viewed superficially, deeper analysis reveals a significant complexity to the methodological issues attending systematic approaches to direct observation (cf. Ray et al., 2011). Although many of these complexity issues are better left for in depth consideration in Descriptive Research Methods courses than in a Learning course, we include several workshops illustrating the issues of objectivity and methodological systematization as major requirements of the method.

A series of in-class workshops are used to illustrate the role of direct and systematic observation of multiple behaviors in descriptive research and how one collects data relating to Catania's (2007) discussion of "behavioral hierarchies." In addition to these in-class exercises, an out-of-class activity on observation and the multiple-behavioral effects of habituation to a novel environmental setting (i.e., continued simple exposure) becomes our first assignment using *CyberRat*. This habituation assignment is used specifically to introduce students to two concepts.  The first concept is the use of cumulative recording graphs that show the rate-of-occurrence for select categories of behavior. Such graphs are a commonly used tool in operant psychology for graphing the data from bar/lever pressing. The second concept introduced in this exercise is how generalizations can be drawn from simple observation operations when they are combined with use of another of Catania's (2007) experimental operations: *Establishing Operations* (see Table 1).

Establishing operations are an example of the use of a prior experimental manipulation to modify the effects of a subsequent experimental operation.  Historically, the most common example of this operation, which we will visit later in another *CyberRat* assignment, is the use of varying periods of deprivation of a stimulus (e.g., removal of food or water) to establish a motivating/reinforcing function for that stimulus. Habituation reflects a similar process.  In fact, there are arguments in the literature that satiation to a previously deprived stimulus is really a type of habituation process (cf. McSweeny & Murphy, 2000; McSweeny, 2004).

We use a habituation assignment with *CyberRat* (see Table 2) to illustrate that data from simple observation operations may be modified by the establishing operation of merely having time pass during observation periods. This implies that behavioral hierarchies are not static phenomena. Although some behaviors occur more frequently than others, these hierarchical arrangements themselves are fluid. And through careful observation we may come to understand their changes across time and circumstance.

Informal observations of laboratory rats during their first exposure to a relatively confined chamber shows that these animals typically begin by exploring the perimeters of that environment by moving about while poking their noses into corners, crevices, and floor openings as well as engaging in a lot of rearing to sniff the walls and ceiling. Only after

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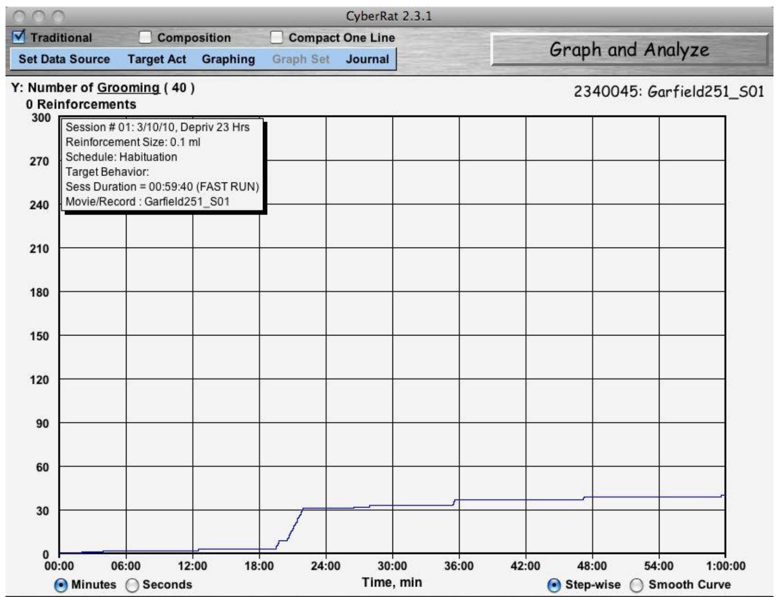
Table 2. Details of the first assignment on Observation and Establishing Operations using *CyberRat*: Behavior during a habituation session.

OUT-of-CLASS LAB ASSIGNMENT:

First, select a new naïve rat in the *CyberRat* colony room. Then go to the Parameters screen and select Habituation as the "schedule." Set the Simulation options to "Fast-run/No-Video" and type in 60 for the minutes of the Session Duration. After the session is complete, save the Video record when prompted—in fact, ALWAYS SAVE VIDEO records of ALL sessions. Now, select the graphing icon and when you get to the Graph and Analyze screen, select "Grooming" as the behavior to be graphed as a cumulative response record showing when the behavior occurs throughout the 60 min session. Now graph "nosing front left corner" as well. In your next written Lab Report be prepared to include the graphs in your results section along with a description of their implications. For example, is grooming a high rate or low rate behavior (and to what benchmark are you comparing it)? Does it have the same rate of occurrence in each successive 10 min-interval across the hour, or does it tend to occur in specific periods? Which ones? Did you anticipate this from your readings about the principle of "Behavioral Hierarchies?" When you write your Lab Report, be sure to cite any literature sources you have used.




*Example Figure 2:* Sample of data illustrating typical second-quarter-of-session concentrations of occurrences for Grooming behaviors across a 60 min session.

some elapsed time (typically around 15-20 min) will the animals turn attention to themselves and begin grooming or scratching. Subsequently, they return once more to patterns of moving about.

These phenomena are illustrated by the *CyberRat* assignment. For example, the cumulative response curve showing how grooming behavior occurs across the hour-long session is illustrated by *Example Figure 2* in Table 2. This figure reveals that grooming occurs in highly specific "bouts," or bursts of higher-rates of occurrence, but only after approximately 15-20 min of exposure to the novel environmental chamber. After approximately 5-10 min duration the bouts end and only occasional and brief reoccurrences are seen across the remainder of the session. While these numeric values may vary from session-to-session and animal-to-animal, it is nevertheless a reliable generalization that grooming occurs at low rates early in habituation and at relatively higher rates near the middle of a 60 min session.

This process of "checking out the environment" before grooming (or "comforting oneself") can also be seen when people change from one setting to another, and the process is typically called "settling in" (a cultural description of the more formal term, habituation). It is a process that many species go through when placed in novel and non-threatening settings, and this process is built into *CyberRat* simulations as well. Thus a reliable outcome of our assigned experiment in habituation is an increase in rate of "mid-session" bouts of grooming followed by lower rates of grooming, thus implying that the behavioral hierarchy is changing. However, rearing up in various locations around the chamber, which is representative of "general

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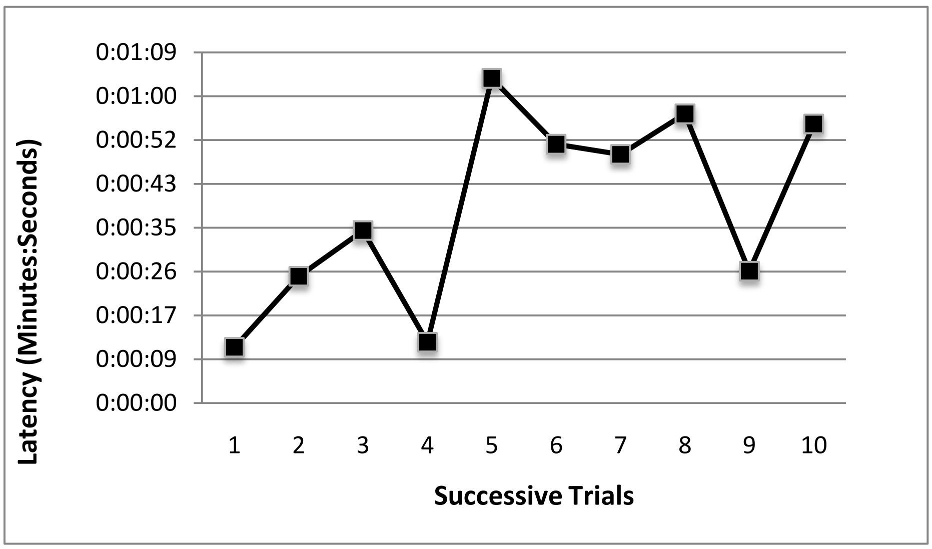
Table 3. Details of a Stimulus Presentation Operation using *CyberRat*: Exploring elicitation through latency measures.

OUT-of-CLASS LAB ASSIGNMENT:

Using *CyberRat,* select for a new session the animal you previously used for the Habituation experimental session. For this experiment set parameters to a VT 90 sec schedule. Select to use the setting called Fast Simulation (this modality setting shows No Video, but instead only a dancing cartoon rat during the experimental session, and thus each session can be completed as quickly as the computer program can calculate the sequences of behavior it WOULD have played if real-time video had been included in the simulation). Set your session to terminate after 11 **reinforcements** (using the number of reinforcements criteria rather than duration of session). For this exercise use the video replay at the Graph and Analyze screen. Determine the latencies by calculating the time between each delivery of water and the subsequent drinking of that water. Drinking is operationally defined as the "eye of the animal disappearing from view as the nose enters the water reservoir." Measure the first 10 presentation-to-drink latencies. If the animal fails to drink prior to the delivery of the next drop, use that delivery time as the "maximum" latency value for that trial.

NOTE for ANALYSIS and DISCUSSION: Long latencies indicate a relatively NEUTRAL stimulus vis a vis Elicitation of the "go-to-drink" behavior of the animal. Enter these latency values in an excel spreadsheet and graph (to be included in the next full Lab Report due after Classical Conditioning). We will consider this session a "baseline" of elicitation latency to be used in future experimental comparisons.




*Example Figure 3:* Illustrative experimental data showing latencies of "drink" behavior following delivery of sound+water across 10 successive presentations via use of a VT 90 sec schedule in *CyberRat.*

exploration and movement," continues at a relatively consistent rate throughout the session. Of course some behaviors are displaced in their relative occurrence during this time of increased grooming, and it may be a challenge left for students to discover which behaviors are most susceptible to this displacement.

If you were observing live animals left day after day in an operant chamber as a "living" environment, you should expect these initial habituation findings to apply only to the initial exposure hour. Longer term habitation would be expected to result in normal circadian variations of activity and resting/sleeping patterns (cf. Ray, Carlson, Carlson, Carlson, & Upson, 1986), which *CyberRat* does not simulate. Since rats are known to be nocturnal animals, sleeping and resting would be more likely to appear during the day, and general movement, exploration, and other "active" response patterns would appear at night. Thus the Ray et al. (1986) citation above is frequently used to illustrate the systematic "tracking" of changes in behavioral hierarchies that occur in virtually all animals across typical 24-hour circadian periods. Such circadian bio-rhythmic patterns in the behavioral hierarchy is another illustration of time passage as an *establishing operation*.

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## Stimulus Presentation Operations, Elicitation, and the Reflex

At this point the course moves from simple *observation operations* and *establishing operations* to consider *stimulus presentation operations* (see Table 1) and the associated principles of elicitation, or what are sometimes called the "Laws of the Reflex" (Skinner, 1938). These laws include: 1) the Law of Threshold; 2) the Law of Intensity-Magnitude; and 3) the Law of Latency. Each deals with the relation between parametric values, both of the stimulus and of the response. Thus the Law of Threshold allows one to consider how the intensity parameter of the stimulus (e.g., how loud a sound is) is related to the probability parameter of the behavior (with the "threshold" typically being defined as the intensity value that produces a 50% probability of responding as intensity of the stimulus is increased systematically). The Law of Intensity-Magnitude describes the relation between increases in the stimulus intensity parameter and the directly proportional increases seen in the magnitude/force of the elicited response. Likewise, the Law of Latency brings to focus the change in time lapse (latency) between the onset of the stimulus and the onset of the elicited response, which is typically an inverse relation with increasing stimulus intensities resulting in decreasing stimulus-response latencies. Having covered these concepts in lecture and reading assignments, we turn to an out-of-class *CyberRat* assignment as detailed in Table 3.

We are careful to point out to students that elicitations resulting from stimulus presentations are measured not only by probability of a predictable response following the stimulus, but also by latency between the stimulus and this response. Some stimuli, however, are not very likely to change behavior when presented, and thus are relatively neutral with respect to presentation effects. This *CyberRat* exercise is specifically designed to demonstrate the relative neutrality of both sound presentations and the presentation of water when that presentation occurs at a distance from the animal (as is typically the case if water is presented at random intervals within the experimental session). Thus latencies between the sound of the delivery of water and a behavior that could be described as "going-to-drink" should be relatively long at first (cf. Table 3, *Example Figure 3*), although they might gradually change across an observation session even though no specific experimental interventions are made to change such latencies (a phenomenon we let students ponder in anticipation of a future assignment).

## Signaling Stimulus Presentation Operations

The future assignment just mentioned is one that investigates the operation of signaling stimulus presentations. The use of two stimuli, one as a signal for another, is Catania's (2007) procedural description of respondent, or classical Pavlovian, conditioning. In one of Pavlov's prototypical experiments a metronome ticking is followed by food, thus making the metronome a signal for the subsequent presentation of food. In class we demonstrate these procedures using several illustrative video clips.

In the *CyberRat* stimulus presentation experiment described earlier, we also presented two stimuli together (sound and water). The relation between hearing the sound and discovering the water, however, is quite random at first because the presentations are made while the animal is virtually anywhere within the chamber. This fact explains our observation of relatively long latencies between hearing the sound and drinking the water. We thus ask students to consider why Pavlov might have harnessed his dogs on the table where his two stimuli were presented. Astute students are likely to pick up on this proximity factor, and if not, class discussion leads students to consider it. We then ask students to demonstrate their use of the same procedure of presenting two stimuli in a *CyberRat* assignment. To assure that the animal is attending to the stimuli, students are asked only to deliver these pairings of sound and water when the animal is near and looking directly at the hole where water is dispensed. Thus in *CyberRat*, classical conditioning is demonstrated by what is typically referred to as "magazine training" procedures.

Prior to shaping any new behavior, it is common to pair a sound or light with delivery of a primary reinforcer, such as food or water, because the sound thereby acquires not only a new conditioned elicitation function (i.e., approaching the reinforcer), but also a conditioned reinforcement function. This secondary or conditioned reinforcement function allows a trainer to immediately reinforce any desired behavior via the presentation of an ambient sound or light (hence the common use of "clickers" in pet training).

In Stage 1 of the assignment detailed in Table 4, classical conditioning is assumedly taking place. However, this assumption requires an independent test to verify that successfully conditioned responding has been established. Stage 2 accomplishes this test by demonstrating a comparative decrease in "go-to-drink" latencies (cf. Table 4, *Example Figure 4*). In fact, such short-

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Table 4. Details of Signaling Stimulus Presentation Operations using *CyberRat*: Exploring applications of classical conditioning for magazine training and conditioned elicitations.

OUT-of-CLASS LAB ASSIGNMENT:

STAGE 1. Using your previous experimental animal in *CyberRat*, conduct another 60 min (with video ON) Session, but this time with the "manual reinforcement" menu setting selected under Schedules but the Bar reinforcement OFF. Each time the animal is in FRONT of the Water Reservoir, approximately a head's length away and looking in that direction, click the manual reinforcement button to deliver water. Do this 30 *different* times. After these 30 stimulus pairings (sound of delivery plus water), we will (in the NEXT STAGE of this assignment) test for a change in your previously measured latency by repeating our previous experiment. There are **no** graphs or laboratory reports associated with this specific stage in the assignment!

STAGE 2. In *CyberRat* again select for a new session the same animal you have used previously. For this experiment, once again set parameters to a VT 90 sec schedule. Select to use Fast Simulation (No Video) and a session termination after 11 reinforcements (using the number of reinforcements criteria rather than duration of session). Measure the first 10 sound presentation-to-drink latencies in this session. If the animal fails to drink prior to the delivery of the next drop, use that delivery time as the "maximum" latency value for that trial.

Reminder: Relatively long latencies can indicate a relatively NEUTRAL stimulus vis a vis Elicitation of the "go-to-drink" behavior of the animal. Plot your new values along with your original stimulus presentation values in your excel spreadsheet and re-graph. What has happened to your previously long latencies after your administration of 30 trials of Classical Conditioning?

Time to write our Laboratory Report: Write a complete Introduction and other appropriate sections for this Lab Report. Focus the report exclusively on your *CyberRat* experimental series. First describe how psychologists begin to systematically analyze how environments stimulate and alter behavior via stages of successively complex *research operations*. Who can you cite for this "operations analysis" approach?

Now consider *Observation Operations* and what scientists can learn from them. Don't forget to cite von Frisch's (1973) work on the dance of the honey bees as discussed in class! Then add *Stimulus Presentation Operations* and describe what understanding this adds to results from more simple *Observation Operations*. This would be a good place to describe how Tinbergen (1952) found that stickleback fish respond to red bellies vs. swollen silver bellies. Now add a discussion of *Signaling of Stimulus Presentations* and what Pavlov (1927) learned from this procedure. Compare Pavlov's observations to those of von Frisch and Tinbergen. How are they alike, and how are they, at the same time, quite different? Now…. Describe your own experiments with *CyberRat*. How did you test stimulus presentations? How did you assess the effects of Signaling Operations (classical conditioning)? How do your data confirm (or not) the effects of classical conditioning (see example data below and insert your own in your results section)? Finally, consider why even these shorter latencies in *CyberRat* are typically longer than those observed with your live animals (hint: video clip lengths). Note in your report that this is one of *CyberRat's* more significant shortcomings as a simulator.

Prior to writing your discussion section, READ Skinner's (1951) "How to Teach Animals" and in your discussion, among previously mentioned related materials, reflect on the relevance and implications of Pavlov's signaling stimulus presentation procedures for Skinner's concept of "magazine training" using "clickers/crickets." (Full Written Laboratory Report Required – see syllabus schedule).

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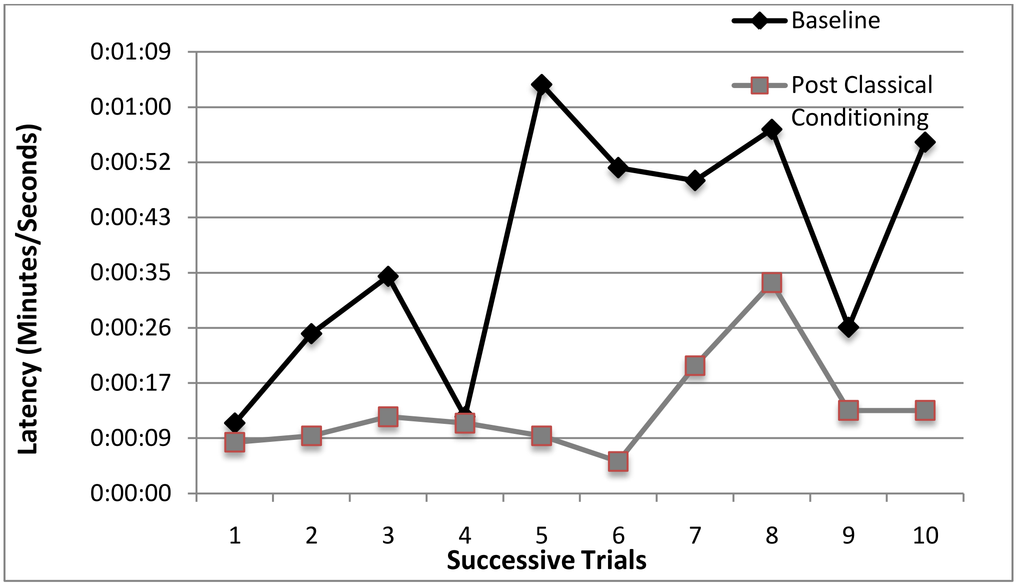


*Example Figure 4:* Illustrative experimental data showing latencies of "drink" behavior following delivery of sound+water across 10 successive presentations via use of a VT 90 sec schedule in CyberRat before (Baseline) and after 30 trials of "magazine training" (Post Classical Conditioning).

latency responsiveness is typically used during magazine training procedures to "test" whether a sufficient number of classical stimulus pairings have been presented to make sound an effective elicitor.

Consequential Operations (Operant Conditioning)

For the sake of brevity without sacrificing the breadth of phenomena illustrated, the bulk of our presentation of operant response shaping of bar pressing and its many associated phenomena, including deprivation/satiation, extinction, alternative scheduling effects, etc., will be presented with highly reduced accompanying narrative. We don't feel it is necessary to include the extensive explanations that we have been using to establish why each experiment is assigned. It should be sufficient to point out that we use reading assignments, both of Catania (2007) and of the *Tutorials* (Ray et al., 2005) and their associated on-line "certification tests." These assignments are accompanied by our use of in-class video clips, lectures, and discussions to provide a critical context for the assignments presented in Tables 5-7. The text within each assignment as it is given to students, along with a brief graphic presentation of the sample results, should provide a sufficient description for professional readers to understand the exercises and their intended pedagogical functions. As a point of emphasis each assignment is given a header that reflects the specific experimental operation illustrated with reference to Catania's taxonomy presented in Table 1.

Tables 5 – 7 illustrate in order:

1) response shaping of bar pressing (consequence operations) and the differential effects of hours-of-deprivation (establishing operations) on subsequent sustained and steady-rate responding under continuous reinforcement (CRF) schedules of water that is presented as a consequence of bar pressing (Example Figure 5 in Table 5);
2) the effects of breaking or ending that consequential relationship (extinction and spontaneous recovery—as illustrated in *Example Figure 6* in Table 6);
3) the ease of post-extinction retraining (*Example Figure* 7 in Table 7) and the phenomenon of ratio-strain if intermittent schedules are attempted without progressive intermittency (*Example Figure 8* in Table 7); and
4) how small and progressive shifts in an intermittent schedule can generate the very high, but temporally patterned, response rates characteristic of fixed ratio schedules of reinforcement (*Example Figure 9* in Table 7).

Advanced Intermittent Schedules of Reinforcement

Exercises Using *CyberRat*

A friend and colleague, David Eckerman, at the University of North Carolina – Chapel Hill has used the following exercises in his Learning course to extend *CyberRat's* use to illustrate

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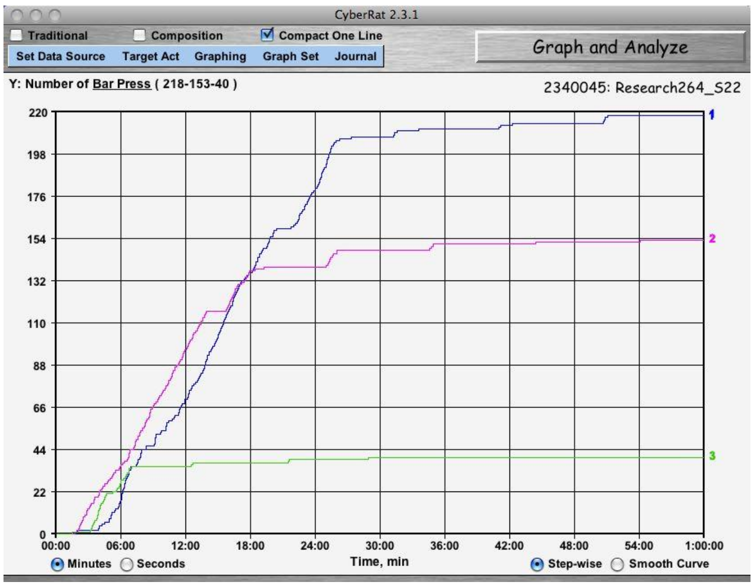
Table 5. Details of Consequential Operations and the impact of Establishing Operations on these Consequential Operations using CyberRat: Shaping a new operant response, the rate of that response under a Continuous Reinforcement (CRF) schedule, and the impact of alternative durations of pre-experimental deprivation on within-session satiation to water as a reinforcer.

STAGE 1**.** Read the *Learning & Conditioning Tutorials* Appendix Topics, which, in addition to being linked from within the "Shaping" topic of the online *Tutorials*, is also downloadable as a pdf at the bottom of the following URL: http://www.ai2inc.com/AIDownloads/AIDownloads/chpt_downloads.html

STAGE 2**.** Using video ON, select the same animal you have already run through Habituation, Elicitation Testing, and Magazine Training. Select under Schedules the "Manual Reinforcement with Bar Reinf On" to conduct as many 30 min Sessions in *CyberRat* as might be required to successfully *shape your animal to BAR PRESS* consistently for more than 10 bar presses. Upon successful completion, conduct 3 more sessions of 60 min each using the CRF Schedule (all 3 may be conducted using FAST SIMULATION / No Video) and be prepared to describe:

**a)** *Bar-press warm-ups* as habituation to being introduced into the chamber, and

**b)** *Satiation* as another potential form of habituation to water (cf., McSweeny & Murphy, 2000; McSweeny, 2004). What do you think is the role of alternative settings for deprivation regarding how fast the animal reaches satiation in CRF sessions? How would you investigate this in *CyberRat* (hint: an example graph of some experimental probes appear below using 23 hours vs. 12 hours, vs. 1 hour!) Try your own ideas yourself through experiments and be ready to report your results!




*Example Figure 5:* Sample Bar Press and within-session water satiation results typical of alternative Pre-Experimental Deprivation Settings of 24 hours (labeled as 1 on the right hand Y-axis), 12 hours (labeled as 2 on the right hand Y-axis), and 1 hour (labeled as 3 on the right hand Y-axis). NOTE: This graph was created using the "Graph Set" feature explained on pp. 48-50 in the *CyberRat* User's Guide (available at: http://www.ai2inc.com/Downloads/CyberRat_UserGuide.pdf)

behavioral contrast and other nuances of complex intermittent schedules of reinforcement. His typical results are worth considering in contrast to our earlier illustration that was generated via the simple post-CRF extinction assignment (see *Example Figure 6* in Table 6). Following the experimental series described in stage 4 of Table 7, he assigns six additional 60 min sessions of FR 30, followed by a single 60 min session under Extinction. Sessions are conducted under Fast Simulation Mode so that they are completed within just a few seconds for each session but can later be viewed in real time if desired. He asks students to compare this extinction session to one conducted subsequent to only CRF training (see *Example Figure 6* in Table 6). During the latter sessions of the FR 30 series, students should see a pattern of pausing after reinforcement before returning to a sustained high rate of responding that is maintained until the next reinforcer delivery—a pattern frequently

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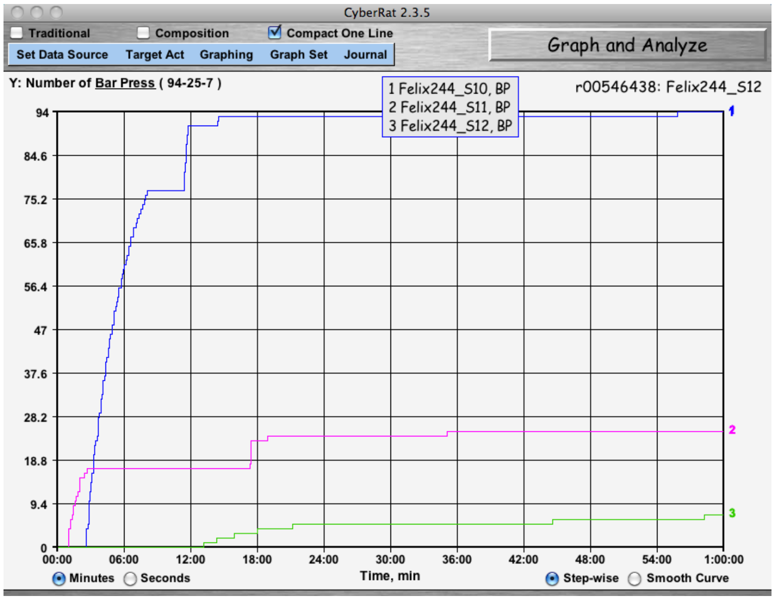
Table 6. Ending pre-established Consequential Operations: The process of response extinction and spontaneous recovery across sessions.

OUT-of-CLASS LAB ASSIGNMENT:

STAGE 1. Select your well trained animal, then go to the Experimental Parameters screen and select CRF again and conduct three new 60 min duration sessions using Fast-Simulation/No-Video mode.

STAGE 2. After completing the three sessions assigned in Stage 1, and while this same animal is selected, return to the Parameters screen and change the Schedule selection to Extinction. While Extinction is the selected schedule, conduct 3 more 60 min duration sessions again using Fast-Simulation/No-Video mode. Following the instructions for using the "Graph Set" feature explained on pp. 48-50 in the *CyberRat User's Guide* (at http://www.ai2inc.com/Downloads/CyberRat_UserGuide.pdf), graph the three Extinction sessions in the sequence they were conducted. Be prepared to include your results from these experiments in a subsequent written laboratory report.




*Example Figure 6:* Sample Results illustrating the extinction of previously conditioned bar pressing across 3 successive sessions labeled 1-3 on the right hand Y-axis. NOTE: This graph was created using the "Graph Set" feature explained on pp. 48-50 in the *CyberRat* User's Guide (available at: http://www.ai2inc.com/Downloads/CyberRat_UserGuide.pdf)

called break-run (see *Example Figure 9* in Table 7). In subsequent sessions, they should see extinction performance that is much higher rate and longer duration (i.e., extinction resistance) compared to extinction in an animal with only previous CRF training.

More importantly, Professor Eckerman also incorporates the following experimental series after the exercise described above. His instructions are to follow the previous extinction session with a post-extinction return to FR 30 re-stabilization via retraining plus several successive 60 min "evaluation" sessions. He then asks students to shift to FI training for a series of 60 min sessions using a fixed time interval value that is equal to the average inter-reinforcement interval found in the FR 30 evaluation sessions. Students follow their FR sessions with the 60 min sessions of FI training using the same time-between-reinforcement value. Because the same "density" of reinforcement is used in both conditions, the subtle differences in patterns and rates produced by these alternative schedules must be due only to the type of schedule and not to the number of reinforcers. One example *CyberRat* experiment using this FR 30 schedule determined that the average time between reinforcer presentations was 73 sec, and thus the FR series was followed with a series of FI 73 sec sessions. Results from this example are illustrated in Figure 1.

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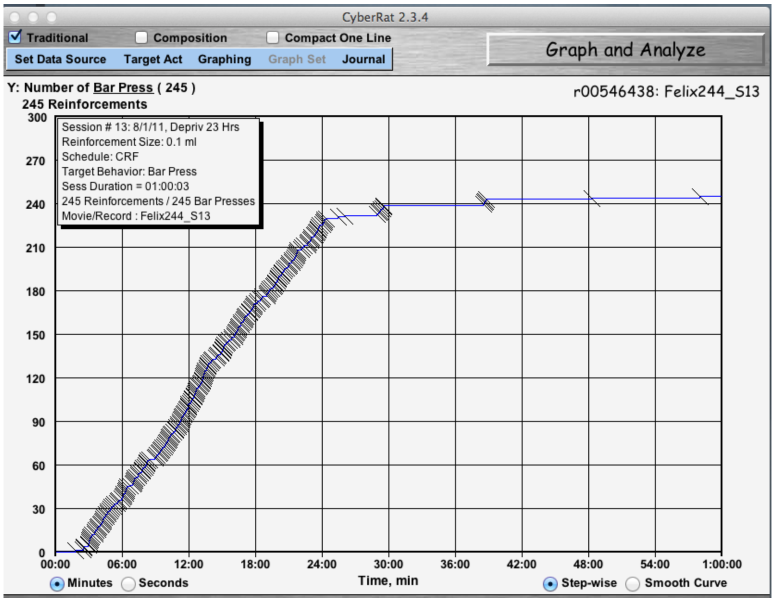
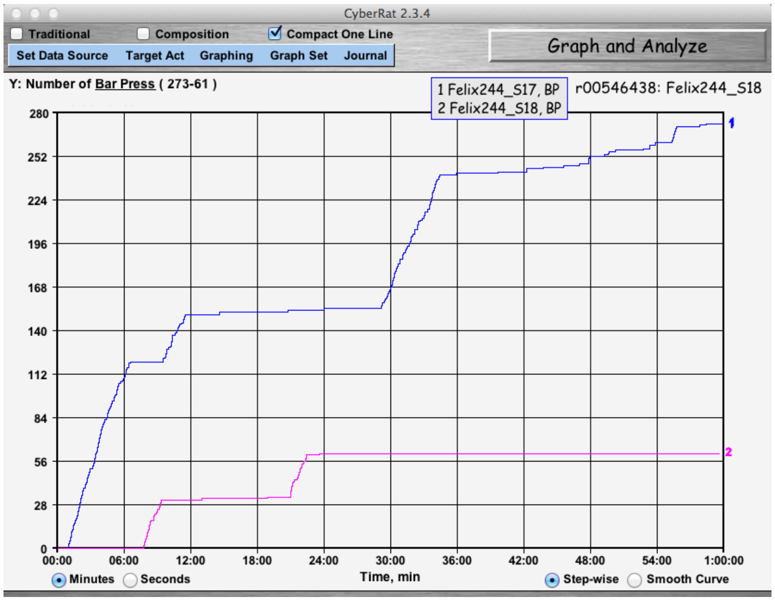
Table 7. A multi-staged assignment on Intermittent Scheduling of Consequential Operations: How response rates change across time under alternative schedules of consequences.

OUT-of-CLASS LAB ASSIGNMENT:

STAGE 1. Retrain your previously conditioned and extinguished *CyberRat* animal to bar press using the "Manual Reinforcement with Bar Reinf On" setting for Schedules. Follow this retraining session with 3 successive CRF 30 min "maintenance" sessions using Fast-Simulation Mode to generate a stable rate of responding. Using your well trained and recently CRF scheduled animal, set the experimental schedule to FR and use the slider to make it an FR 30 ratio. Run five consecutive 60 min sessions using this FR 30 schedule in Fast Simulation mode.




*Example Figure 7:* Sample results illustrating confirmation of Post-Extinction Bar Press Retraining.




*Example Figure 8:* Sample results from two successive Post-CRF Sessions using FR 30 and illustrating a ratio-strain that results in extinction. NOTE: This graph was created using the "Graph Set" feature explained on pp. 48-50 in the CyberRat User's Guide (available at: http://www.ai2inc.com/Downloads/CyberRat_UserGuide.pdf)

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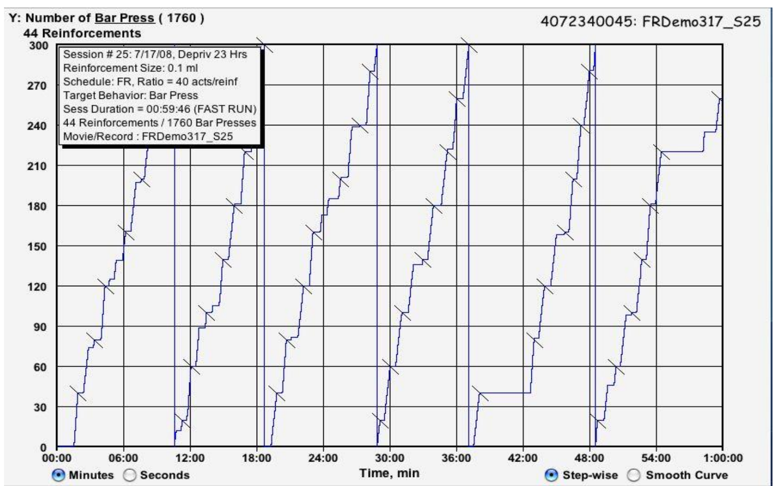
STAGE 2. Consider why your animal may have stopped responding on this intermittent schedule. Look up the concept of ratio strain in Catania (2007) and see how it might apply to the five sessions you just conducted. Be prepared to include this in a formal report.

STAGE 3. Retrain this animal to bar press using the "Manual Reinforcement with Bar Reinf On" setting for Schedules. Follow this with 3 successive CRF 30 min sessions using Fast-Simulation Mode to generate a new stable rate of responding. Now try getting to an FR 30 ratio schedule without straining the schedule. This gradual "successive approximation to schedule" process is called "leaning" the schedule. To lean the schedule successfully, use *Fast Simulation* mode and run your previously Bar-Press trained and CRF maintained animal for successive 60 min sessions in the following order:

Session 1-3 - FR 3
Session 4-6 - FR 10
Session 7-9 - FR 15
Session 10-12 - FR 20
Session 13-15 - FR 30

STAGE 4. Now conduct 5 more 60 min duration sessions in Fast Simulation mode with settings equal to Session 15 (i.e., with FR 30 as your schedule). What temporal patterns in behavioral operating characteristics emerge? **(**Be prepared to include results and discussion of these phenomena in your next assigned written Lab Report).




*Example Figure 9:* Sample illustration of a stable break-run pattern of responding on a well-established FR 30 reinforcement schedule.

## Other Samples of Class and Lab Experiments: Signaling Consequential Operations

The remaining operation not yet illustrated from Table 1 is Catania's (2007) Signaling Consequential Operation, which is his term for discriminative stimulus control of reinforced operant behavior. This operation involves presenting a contextual stimulus that functionally signals that reinforcement contingencies are in effect during the presence of the discriminative stimulus (denoted either as $S^+$ or $S^D$). Typically this stimulus alternates with a different contextual stimulus state that functionally signals that these reinforcement contingencies are not in effect ($S^-$ or $S^\Delta$). Extinction typically takes place during these $S^\Delta$ stimulus conditions.

The discrimination between these stimuli takes place gradually as the animal learns to maintain responding during $S^D$ but to extinguish responding during $S^\Delta$. This gradual development is reflected in a ratio (the discrimination ratio) between the number of bar presses in $S^D$ compared to the total bar presses in the entire session (i.e., bar presses during $S^D$ plus $S^\Delta$). This is the process discovered from the execution of the assignment reflected in *Example Figure 10* in Table 8. This figure shows the "learning curve" for discriminative stimulus control with respect to bar pressing. That is, by session 13-16, the ratio reflects that approximately 90% of all bar presses are consistently occurring only when $S^D$ is the ambient stimulus. Importantly, the minor fluctuations from session to session allow for consideration of how one determines that "stability" has been reached

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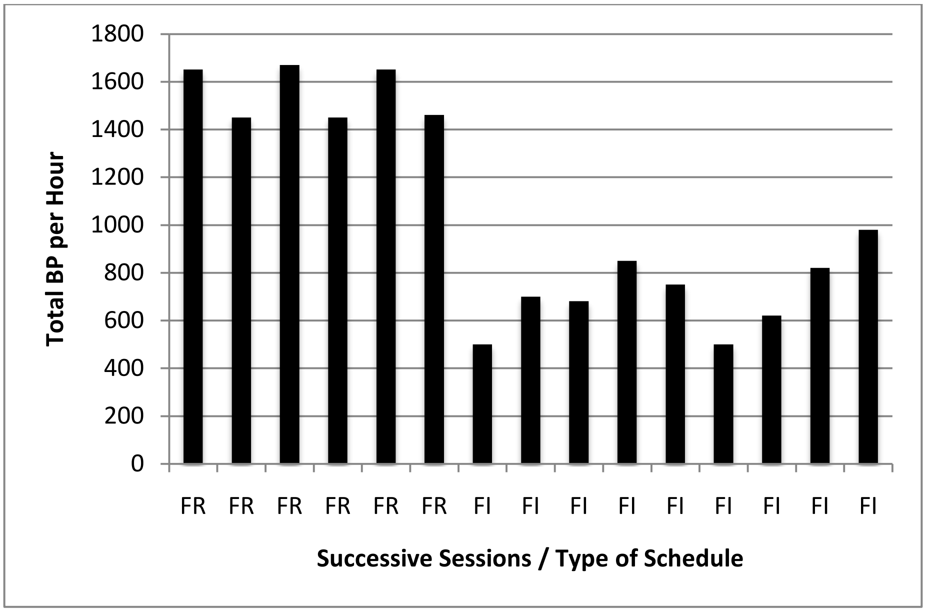


*Figure 1*. A series of successive *CyberRat* sessions applying two equal-density reinforcement schedules is illustrated. A series of stable FR 30 sessions were conducted for 60 min each to determine the average time between reinforcements. This time of 73 sec was used as the defining criteria for a shift to a subsequent series of FI 73 sec scheduled sessions. This illustrates different response rates under alternative conditions of equal densities of intermittent reinforcement.

with variable data. Individual students may expect that their animal's stable ratio might vary from the 90% value of the demonstration animal's performances as well, thus allowing students to discuss how between-subject variability might be different from within-subject variability.

## A Sample of Class and Lab Experiments other than *CyberRat*

### Organizational and Behavioral Management

The experiments described above are almost exclusively those based upon the use of *CyberRat* in our course. Several live animal experiments are also used within the course but have not been considered because of space limitations in the current report. Nevertheless it is relevant to point out that some of the basic experiments first conducted in *CyberRat* are subsequently replicated with live animals. These include magazine training and informal probes for its effectiveness by testing for short-latency "go-to-drink" behaviors when the animal is not at the water station. Students also shape bar pressing, compare CRF rates of responding between their live animals and their simulated animals, evaluate extinction, and experience simple shifts in intermittent schedules of reinforcement.

Also included in the course around mid-semester is a two-week period of lectures and discussions on how applied behavior analysis might be used to solve everyday problems such as work quality and productivity in industry. Lectures and discussion establish the parallels between magazine training and the establishment of functional secondary reinforcement values in artificial token-based reinforcement economies and how this concept applies to the broader field of behavioral economics in general. The behavioral principles studied thus far in the course are also discussed in relation to training of new workers using successive approximation (shaping) procedures based upon a detailed task analysis of their jobs. In addition we consider the role of task analysis in subsequent performance evaluation, as well as productivity and quality management.

These discussions lead to a specific class-engaged task analysis of academic/student behaviors as they might be, or might fail to be, observed within the various discriminative settings that students experience in their courses in general, and in our Learning course especially. The impact of this process and its subsequent application as an option for students to contract for an increase in

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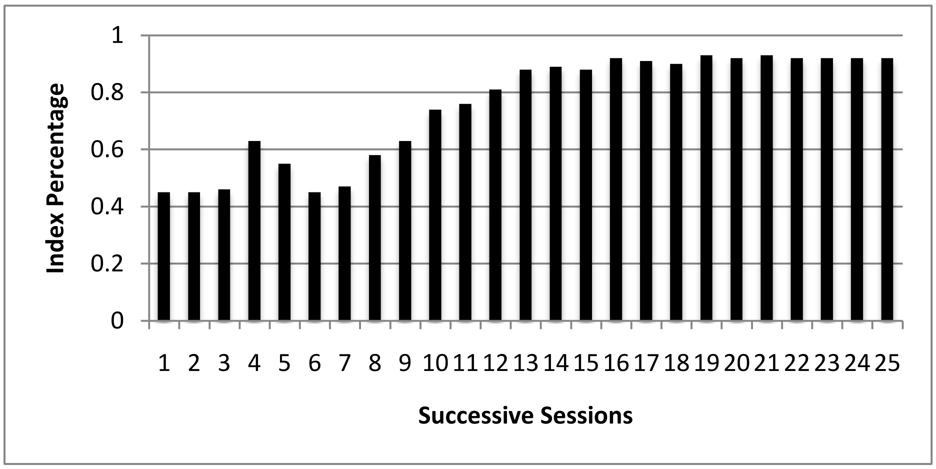
Table 8. Assignment on Signaling Consequential Operations: Tracking the development of reliable stimulus discrimination using the discrimination ratio measure.

OUT-of-CLASS LAB ASSIGNMENT:

Using *Fast Simulation* mode, set *CyberRat's* stimulus control (discrimination) schedules to 60 sec S+ and 60 sec S-, then switch to a VR 10 reinforcement schedule and run as many sessions as required to get a stable discrimination index for 5 successive sessions. Stability will be defined as +/- 5 percentage points around a maximum determined ratio minus .05 discrimination index value (example: .92-.05=.87 in Example Figure 10). Record your discrimination index in an excel spreadsheet and graph the process' development curve. Include results and discussion of these phenomena in a Lab Report on Stimulus Control of Behavior. Complete your lab report by including these data and a discussion of how they address the general concept of stimulus perception.




*Example Figure 10:* Discrimination Index plotted across a series of 25 successive sessions under an alternative 60 sec S+/S- schedule setting for stimulus discrimination.

individual academic performance within our Learning course has been reported in an earlier publication (Ray & Salomon, 1996). We summarize the highlights of this process to illustrate further how behavioral principles are applied within the course as pedagogical techniques for students to experience first-hand. A relatively brief version of the task analysis generated by our in class collaboration (see Table 9) defines simple-to-complex behaviors that students can target for development via a token reinforcement economy, as well as how these target behaviors differ across settings (thus emphasizing discriminative stimulus functions).

The construction and implementation of contracted academic performance has been demonstrated to be a highly effective technique for raising student performance within this course and is an integral laboratory experience even for those students who choose not to participate (thereby self-selecting to serve as experimental controls in this quasi-experimental design). For example the increases in test performance that are illustrated in Figure 2 are the incidental products of near term generalizations from all the contracted "study" behaviors noted in Table 9. As such, the contract is highly effective in generating study skills improvement for those who need remediation most. This results in substantial performance improvements for virtually all students contracting during the second half of the semester compared to their performances during the first half.

Verbal Behavior

The period following construction and implementation of the academic performance contract includes approximately 40% of the entire course. This portion of the course focuses on the second part of Catania's (2007) text, which details verbal behavior. The course includes several student participant experimental demonstrations of verbal learning procedures, including those used by Ebbinghaus' (1885) in his studies of consonant-vowel-consonant (CVC) trigrams. Serial position effects are also demonstrated through student experimental participation.

Finally, the course focuses on other applied behavior analysis techniques as they relate to the teaching of language and non-verbal communication

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Table 9. Illustrated is a task analysis summarizing increasingly complex forms of various behaviors appropriate for alternative educational settings. Each behavior is targeted for contracted token reinforcement designed to increase performance quality and the expansion of student skill repertoires (from Ray & Salomon, 1996, p. 56).

| **Alternative Settings** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Simple** | | **Moderate** | | | **Complex** | |
| **Class-Room** | Attend Class | Take Notes | Ask/ Answer Questions | Discussion in class | Brief Presentation | Oral Report | Teach class |
| | **Simple** | | **Moderate** | | | **Complex** | |
| **Laboratory** | Attend Labs Sessions | Observe Demos | Conduct Assigned Experiments | Write Lab Report | Execute Personal Replications | Design/Execute Original Research | |
| | **Simple** | | **Moderate** | | | **Complex** | |
| **Information Resources** (Library, online, text) | Read Assigned Materials | Highlight and Notate Readings | Outline & Reading Notebook | Suggested Extra Readings | Find Primary Articles | Term Paper/Thesis Primary Research | |
| | **Simple** | | **Moderate** | | | **Complex** | |
| **Other** | Attend Study Group | Make/Take Practice Tests | Apply Concepts in Term Paper | Field Trips | Volunteer in Community | Internship / work | |

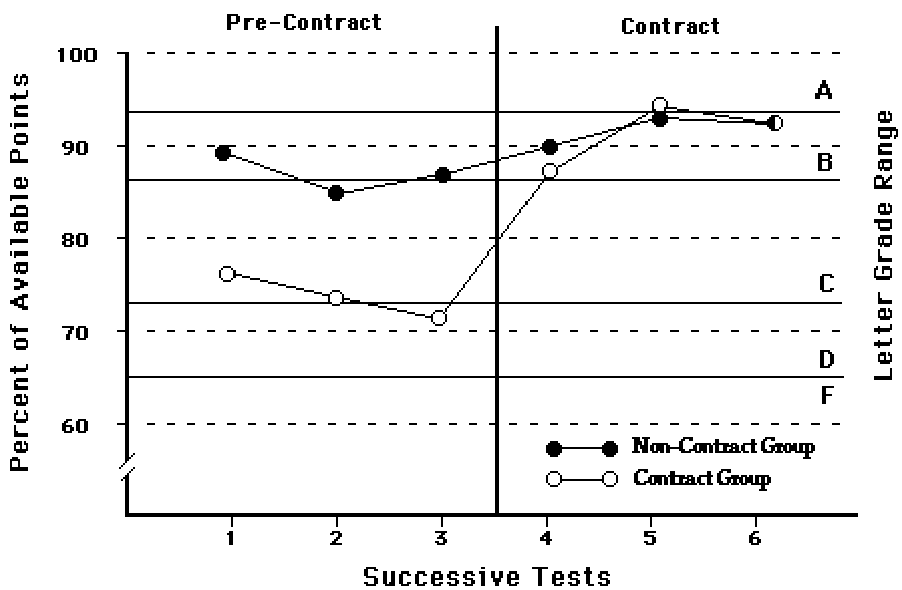


*Figure 2.* Ray and Salomon's Figure 3 (1996, p. 60) illustrating mean percentage of correct points and corresponding letter grades obtained by contracting and non-contracting groups on each test administered during contracting and non-contracting periods of the course.

skills in populations with special needs, such as developmentally delayed and autistic populations. Students in the class use an additional software product called *Train-To-Code* (TTC; Ray & Ray, 2008; Ray, Ray, Eckerman, Milkosky, & Gillins, 2011; www.ai2inc.com/Products/ttc.html). *Train-To-Code* is designed to train students and researchers to make accurate observational recordings (i.e., to accurately "code") based on videos showing multiple examples of behavior. In this specific case, the videos illustrate behavior analytic clinicians using techniques such as errorless training (e.g., Terrace, 1963) via prompts, faded-prompts, and probe techniques in clinical settings. Because TTC is, itself, designed around errorless discrimination training strategies, student participants in these exercises not only learn to identify the procedures when used on others but directly experience them being applied to their own discriminatively controlled coding behaviors—read: "tacting" in Skinner's (1957) verbal behavior terminology. All of this is complemented by assignments of Catania (2007) and the *Tutorials* (Ray et al., 2005).

## Conclusion

We have demonstrated that our course is very much taught in the spirit of the original Columbia series that introduced generations of students to behavioral principles. But in addition to the live animal and student participant model used in that early series, our course incorporates to the greatest extent possible the advancements in computer-based instruction and laboratory simulation that derives from the principles being taught. Thus students simultaneously learn not only to discriminate and appropriately label specialized behavioral processes and principles, but they also experience them first hand through experiments they conduct and through applications of the principles to their own learning.

In closing, one remaining aspect of our course is relevant to consider. This is its lasting effectiveness and contribution to our overall Psychology curriculum. The Rollins Psychology Department's program assessment process relies heavily upon all graduating seniors being required to take the standardized Major Field Test in Psychology during the semester immediately before graduation. Last year (Spring of 2011) our Psychology major program was in the 80$^{th}$ percentile of the sample of 365 participating institutions in their total test scores, and the Learning and Cognition sub-scores of 90$^{th}$ percentile was the highest of all sub-score areas. The average for the past five graduating classes is the 79$^{th}$ percentile on the Learning and Cognition sub-score, which also represents the highest mean of all sub-scores each year. We continue to have confidence in the lasting educational value our course has for our majoring students, and believe that the convergence of the various kinds of learning activities we have described plays a critical role in establishing the persistence of that value.

## Authors' Note

*CyberRat*, the *Learning and Conditioning Tutorials*, and *Train-To-Code* software systems are commercial products developed and distributed by (AI)$^2$, Inc., and the senior author (R. D. Ray) is both a stockholder and executive officer in this company. The authors wish to express their appreciation to Dr. David A. Eckerman for his permission to include his *CyberRat* assignments and for his editorial comments on early drafts of this paper.

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