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# Acquisition of Stimulus Control

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Methodological and applied issues related to stimulus control and the discriminated operant are articulated along with results of a laboratory demonstration of acquisition of stimulus control in a single rat. The rat was exposed to a three-term contingency over one 200-trial session. The rat had to press a lever when a light was turned on, and this response delivered a single food pellet. Lever presses were not reinforced when the light was off. The process of acquisition of stimulus control progressed in three stages. First, the response was repeated after each reinforcer in short extinction bursts. Second, the latency of responding to the stimulus decreased to a few seconds. Third, the response rate in the absence of the stimulus declined gradually across the session to a very low rate of less than one response per minute. The final performance was an almost perfect discrimination with almost no responses when the light was off and a very quick reaction when the light turned on. To examine the reinforcing properties of the stimulus, a test was performed where the rat had to press another lever to turn the light on. This response was quickly acquired. The main results were replicated with a second rat. The background for stimulus control research and methodology are interwoven with the results to provide a pedagogical presentation of issues related to acquisition of stimulus control. The results are also used to highlight conceptual issues and generality of stimulus control as well as issues related to application of stimulus control methodology in clinical and educational environments.

*Key words:* discrimination, basic research on stimulus control, application of stimulus control, single-session acquisition of stimulus control, single-subject design, B. F. Skinner

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Stimulus control refers to the effect a stimulus has on behavior. It changes behavior. For example, a light turns on in a Skinner box and a rat presses a lever within a few seconds. Later a tone turns on, and the rat quickly presses another lever. The two levers are pressed only rarely or never in the absence of light and tone. These types of control of behavior are acquired and maintained with the use of contingencies of reinforcement. Such acquisition of stimulus control has profound implications for application of basic methods of behavior management in educational and therapeutical settings. For Skinner (1938), a science of behavior should identify the important aspects of an organism's environment that modify and maintain behavior. Before his work, researchers primarily examined reflexes, the stimulus – response functions that organisms bring to the world. Such reflexes could also be modified through conditioning as in Pavlov's (1927) work. Skinner's initial research established the conditions under which one can study voluntary or free-operant behavior. The behavior operated on the environment, as exemplified by a lever press producing delivery of a food pellet to a food deprived rat. This operant behavior was "free" from eliciting stimuli in contrast to reflexes that required a triggering or eliciting stimulus (Iversen, 1992). Skinner (1933) also studied how such operant behavior could come under stimulus control. In short, first he reinforced lever pressing in rats under a Fixed-Interval schedule of 5 min for three

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1-hr sessions. Then he introduced a light at the time of reinforcement so that the reinforcer was only delivered when the rats made a response after the light had turned on. Over 10, 1-hr sessions the response rate decreased in the absence of the light, and the latency to respond to the light shortened. Once the control by the light is established, the stimulus has the function that it controls or "guides" the behaving organism to make a specific response at a specific time (i.e., when the stimulus is presented). Often such behavior is called a discriminated operant. And the stimulus, when it controls behavior, is called a discriminative stimulus. Customarily one describes the situation as *the stimulus sets the occasion for the response to be reinforced* and that the response is emitted to the stimulus and not elicited, as for conditioned reflexes (e.g., Catania, 2017; Cooper et al., 2019). The process by which such behavior is established is called operant discrimination (e.g., Skinner 1953).

**Three-Term Contingency**

The procedure or logic of a discriminated operant is often described as a *three-term contingency*. The three terms are the stimulus, the response, and the reinforcement. The contingency specifies that the response is reinforced only in the presence of the stimulus and not at other times. The outcome of continued exposure to this contingency is that the behavior has a much higher probability of occurring during the stimulus than when the stimulus is absent. The discriminated operant is a clear demonstration of environmental control of voluntary behavior. Skinner (1953) wrote about the process of discrimination that: "Its importance in a theoretical analysis, as well as in the practical control of behavior, is obvious: when a discrimination has been established, we may alter the probability of a response instantly by presenting or removing the discriminative stimulus" (p. 108). Skinner added that: "The environmental control has an obvious biological significance. If all behavior were equally likely to occur on all occasions, the result would be chaotic. It is obviously advantageous that a response occur [sic.] only when it is likely to be reinforced" (p. 108).

Stimulus control is an extensive area of both basic research and application with a considerable number of publications spanning decades since Skinner's original formulations. Informative sources are Dinsmoor's (1995a, 1995b) tutorials on stimulus control and a plethora of textbooks from Keller and Schoenfeld (1950) to Catania (2017). Reviews of advanced cases and analyses of stimulus control are found, for example, in Terrace (1966) and Harrison (1991). Sidman (2008) articulated how vast the stimulus control area has become and provided examples of the complexity of both research and data analysis in stimulus control research. Arntzen and Saetherbakken (2021) reviewed the considerable research on advanced and complex stimulus control from Sidman's laboratory that preceded his important work on stimulus equivalence. Even the simplest procedures of stimulus control, such as reinforcing a response only when a light is present, can quickly become complex in results and analysis.

**Methodology of Stimulus Control**

The purpose of this article is to illustrate the process of acquisition of "simple" stimulus control using an actual example of a laboratory demonstration of stimulus control with a rat as the experimental subject. As a pedagogical illustration, Figure 1 shows a schematic drawing of the three-term contingency and the behavior changes that take place from when discrimination training starts to when the discriminative stimulus controls behavior. The top segment of three lines represents the condition when discrimination training starts. The bottom segment represents conditions when the discrimination is established. In each segment, the first line moves down when the stimulus is presented (e.g., a light is turned on) and stays down until it is turned off. The second

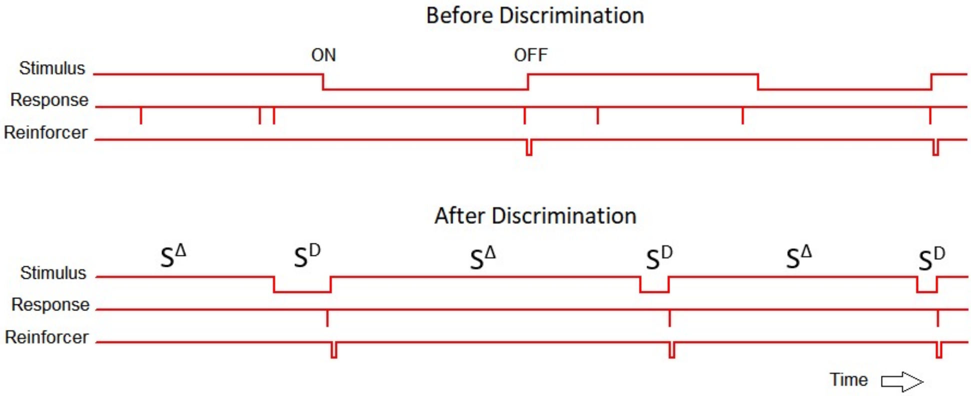


Figure 1. Schematic illustration of the three-term contingency and the expected behavior changes. Note. The display shows two segments, Before discrimination and After discrimination. For each segment, stimulus presentation shows in the top line, response occurrence in the second line, and reinforcer delivery in the third line. The display illustrates the three-term contingency by showing that responses are only reinforced during the stimulus and never in the absence of the stimulus. After discrimination is established, the stimulus during which the response occurs and is reinforced is called $S^{D}$ (pronounced S-dee), and the absence of the stimulus where the response is absent and not reinforced is called $S^{\Delta}$ (pronounced S-delta).

line moves down each time a response (e.g., a lever press) occurs. The third line moves down each time a reinforcer is presented (e.g., pellet delivery). In the top display, responses occur sporadically and are not controlled by the stimulus. At some point a response happens to occur (i.e., the rat presses the lever) while the stimulus is turned on and the three-term contingency therefore results in delivery of the reinforcer the moment the response occurs and the stimulus turns off, as shown in the top display. In the bottom display, the response now occurs quickly each time the stimulus is turned on. In addition, the response is absent during the periods where the stimulus is off. After the discrimination is established, the terminology for the two conditions is $S^{D}$ (pronounced S-dee) for the discriminative stimulus (i.e., the light) and $S^{\Delta}$ (pronounced S-delta) for the period when the light is absent. As is evident from the display, the resulting performance is environmental control of when the response occurs, such that the probability of the response is much higher during the stimulus than in the absence of the stimulus. Notice that both $S^{D}$ and $S^{\Delta}$ are discriminative stimuli, $S^{D}$ makes behavior occur while $S^{\Delta}$ stops or inhibits or prevents behavior. Another way of paraphrasing the terminology in simple discourse is that the $S^{D}$ permits the behavior to occur while $S^{\Delta}$ does not.

What is the method of establishing the discriminated operant, and how does the behavior of the rat change because of this method? For many years I have conducted research on stimulus control in our animal behavior laboratory at University of North Florida. Undergraduate students have established routine demonstrations of stimulus control using rats as subjects and food as reinforcement. Here follows a description of the method and results of such customary demonstrations of acquisition of stimulus control in an animal laboratory. There are some setting factors that must be established before such a demonstration can be successful. First, the equipment must be adequate for the situation. Various commercial companies provide equipment for research with rats. Using rats as subjects, the prerequisite conditions are a healthy rat that is several months old. If food reinforcement is used, then the rat must be food deprived which consists of reducing the body weight over a 2-week period with somewhat restricted diet to 85% of its normal weight. Food pellets used during research are small, 45 mg, commercially available pellets. They are delivered through an automated feeder into a tray on one wall in the Skinner box which has two levers, one on each side of the food tray. For the present demonstration experiment, a single light was placed above the right lever. Using food reinforcement, the rats are fed each day after having been in the experiment. Electronic equipment records a press on the lever, turns the light on and off, and delivers single food pellets. Some companies provide already made programs that can be used for demonstrations and research. Many researchers, however, prefer to make their own programs because one can better arrange for novel conditions and one can record and store the data one is interested in. For details regarding this type of experimental setup see, for example, Iversen (2008).

The method of establishing a discriminated operant is to develop a situation with differential reinforcement across stimulus conditions (Skinner, 1953). This means that reinforcement for lever pressing is provided during the light but never for lever presses in the absence of the light, as illustrated in Figure 1. The term differential reinforcement is a technical term that means that reinforcement for a response is arranged differently in different situations, here under different stimuli. The three-term contingency must be precisely programmed and adhered to all the time. This is best accomplished using automated equipment. In addition to the differential reinforcement arrangement, establishing a discriminated operant requires presenting several occasions where the response can be reinforced during the light. One presentation of a light that sets the occasion for reinforcement of the response is often called a trial. A given training period, often called a session thus has many trials. The trials are separated by the light-off periods, often called inter-trial intervals, abbreviated ITI. This abbreviation will be used for the rest of the paper. For example, the average ITI may be set at 1 min and vary around that value. Thus, a 1-hr session may have 60 trials. In addition to these arrangements, there is an additional contingency which arranges that the light cannot turn on right after a lever press that happens to occur during the ITI. This can easily be arranged in the automated program that controls the experiment. For example, if a response occurs within the last 15 s of a given ITI period, then the end of that period is reset to 15 s thus guaranteeing that there is always at least 15 s passing between a response and trial onset. Once the discriminated operant is established, the trial is the same as the $S^D$, and the ITI is the same as the $S^\Delta$. The reason for this terminology is that stimulus control is not present at the beginning of training, and therefore the $S^D$ and $S^\Delta$ are not appropriate stimulus control terms until the discrimination is established.

**Experimental Demonstration of Acquisition of Stimulus Control**

To illustrate a customary acquisition process of a discriminated operant one rat was placed on a procedure as described above. To enable the rat to contact the three-term contingency, one must first establish a baseline of relevant behavior. Thus, the rat had previously been trained to receive pellets from the food tray upon delivery and to press either lever to produce food pellets in a single session with 25 pellets for each lever. To enable acquisition of stimulus control, the rat was exposed to the discrimination procedure which lasted for 200 trials in one single session. The stimulus was the light over the right lever in the Skinner box, and the response was pressing the right lever. The experiment was controlled by a custom-made program written in Liberty Basic by the author. The specific parameters were as follows: The maximal stimulus duration was 60 s (i.e., the light turned off after 60 s without a lever press). The ITI was an average of 45 s and varied randomly from 6 s to 90 s. However, as described above, a response on the right lever could not occur right before stimulus onset and this delay was set to 15 s.

Figure 2 shows a cumulative record of lever pressing for the entire session (which lasted 2 hr and 31 min). (This record was produced electronically from a data file that stored events in 1-s time periods; a custom-made program written Liberty Basic converted the stored data to the cumulative record

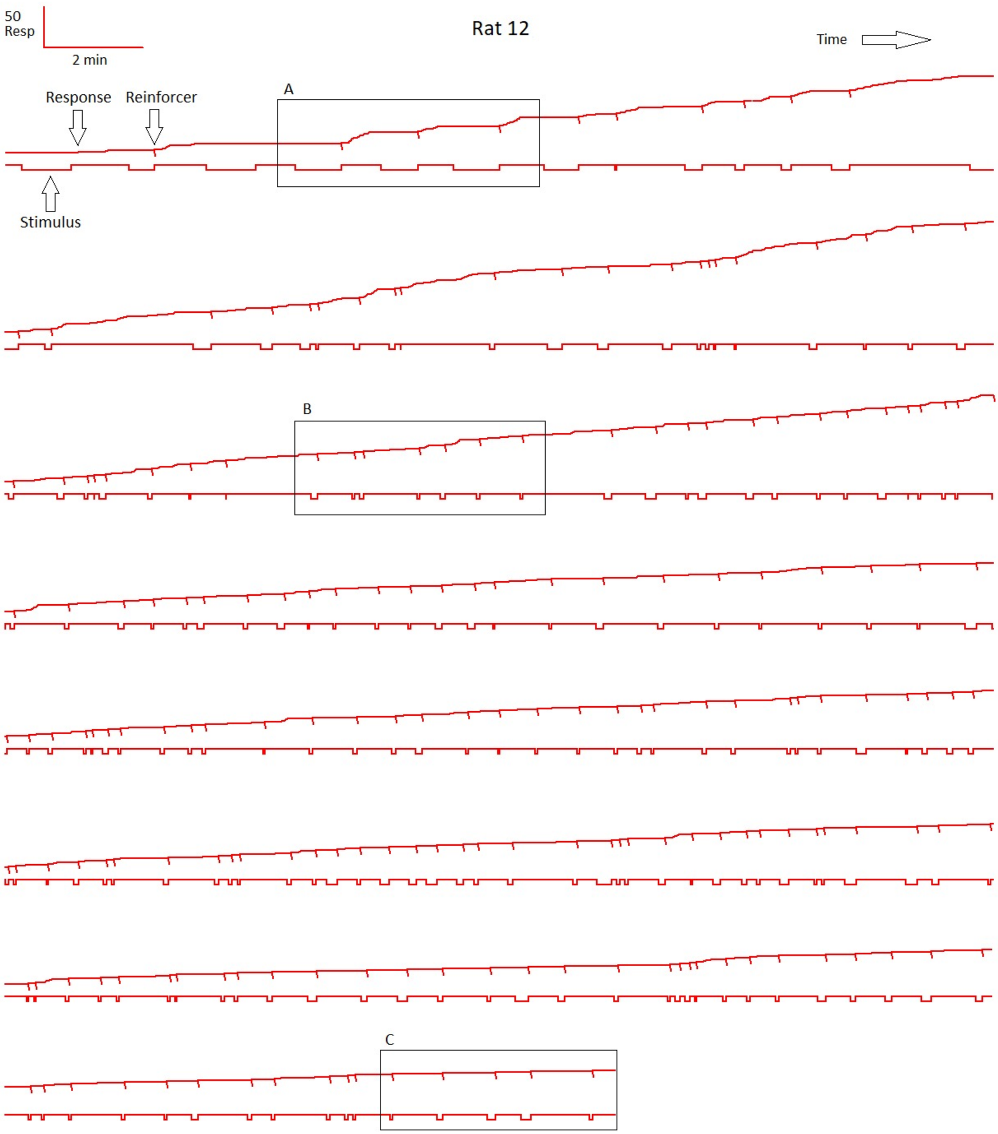


Figure 2. Cumulative record of lever pressing for a continuous session with 200 trials for one rat. Note. The pen moves up for each response. A mark indicates reinforcement. The second line indicates light presentation. Each segment is 20 min. Boxes A-C are selected highlights and appear in event-recorder displays in Figure 3.

image for visual analysis of session data. The electronic cumulative record closely mimics traditional cumulative records produced by ink pens on slowly moving paper.) The lower trace shows the stimulus duration. Because the stimulus ends when the rat presses the lever, the stimulus duration is identical to the latency except for trials when the rat does not respond and the stimulus then ends after 60 s. Reinforcement is marked on the response trace as a small vertical tick mark. To show the entire session in one view, it was necessary to break the record into 20-min segments and to reset the responses pen for each segment.

The rat did not press the lever during the first and third trial, and these trials terminated after 60 s as seen on the left side of the top display. Thereafter, a response occurred during all trials. During the first reinforced trials, the rat responded several times on the lever right after reinforcement, as is evident in small extinction-like curves. This illustrates the immediate strengthening effect of single reinforcements in novel situations, as also reported by Skinner (1938) and Henton and Iversen (1978). Responses made when the stimulus is off during the ITI do not produce reinforcement. Box A around trials 4-6 refers to the segment in Figure 3 that shows the same data in event record displays, like Figure 1. These bursts of responses after reinforcement disappear within the first 20-min period and are replaced with responses that spread out throughout the ITI, as seen at the end of the first 20-min segment in Figure 2 and the beginning of the second segment. Across the next hour or so the responses become rarer during ITI, as illustrated in Box B (see Figure 3). Reaction times to the stimulus also become shorter very quickly as seen in the second segment and then they remain short for the rest of the session. Thus, the earliest behavioral effect of exposure to the three-term contingency is an initial bursting of responses right after reinforcement, which basically are miniature extinction curves (e.g., Skinner, 1938). Thereafter, the reaction time to the stimulus gets shorter and all stimuli control occurrence of a response. Then the responses still occur during the ITI and are spread out as opposed to occurring only right after reinforcement. Over the next several trials the latency shortens further, and the responses during the ITI are further reduced. Eventually, response-free ITI periods become more and more frequent. For example, in the middle of the next to last segment, there are 16 ITI periods in a row without a single response. The session ends with short latencies and several trials in a row without responses during the ITI, as shown in Box C (see Figure 3). Thus, the final performance after 200 trials looks just like the lower segment in Figure 1. The three-term contingency enabled the rat's behavior to gradually adapt to the prevailing conditions. Just as the environment controls the rat's behavior, the rat's behavior also controls the environment, as the reinforcer only is delivered when the rat presses the lever during the stimulus. This enabling of interplay or interdependency of behavior and environment is crucial for the development of stimulus control of behavior.

While the behavioral difference between the first 10 min of the session and the last 10 min of the session is dramatic, one may reasonably ask at what point is the discriminated operant established? Should the latency be below a certain value? Should all ITI periods be response free? One cannot point to a given trial and say that here is the first evidence of the discriminated operant. To help answer this question, Figure 4 shows averages of the latency and the response rate in the ITI for blocks of 10 trials. It is, of course, an arbitrary determination to select blocks of 10 trials. The average latency quickly drops to around 5 s and then remains at that level for the rest of the session, with some minor exceptions. The response rate in the ITI, however, drops much more slowly and keeps dropping throughout the session reaching less than 1 response per minute after about 120 trials. Figure 4 also shows a "discrimination index" which here is defined

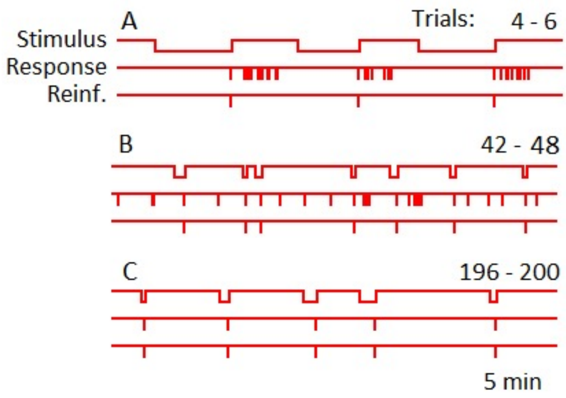


Figure 3. Segments cut out from Figure 2 illustrate details of stimulus, response, and reinforcer.
Note. Selected segments from the cumulative record of lever pressing in Figure 2. Each segment shows a 5-min period. Segment A, showing the first three successive reinforced trials, illustrates that lever pressing occurred in a bout right after reinforcement of lever pressing during the stimulus. Segment B, about 50 min into the session, illustrates that lever pressing occurs much sooner when the stimulus turns on; in addition, the response occurs sporadically between stimulus periods. Segment C covers the last five trials of the session illustrating short latencies and that no responses occur between stimulus periods. This last segment shows the fully developed discriminated operant as depicted in the lower segment of the schematic in Figure 1.

as the response rate during the trial divided by the response rate during the trial plus during the ITI. This index can vary from zero to 1, with a value of zero representing that no responses occur during trials to a value of 1 representing that no responses occur during the ITI. A value of 0.5 represents equal responding in trial and ITI periods. The discrimination index begins at a value below 0.5 because, as the cumulative record in Figure 2 shows, the first reinforcers induce bursts of responding resulting in a high response rate in the ITI. The discrimination index increases gradually throughout the session and reaches 1 or almost one toward the end of the session, corresponding to the more frequent response-free ITI periods that are apparent on the cumulative record in Figure 2. Obviously, the discrimination is fully established by the end of the session. But is it established prior to that time? The averages do not answer the question about when discrimination is established. However, the averages confirm the visual inspection of the cumulative record from the whole session. The latency becomes short and stays short, long before the responses in the ITI reach a low level or become absent. It would not represent all performance if one were to conclude that the discrimination is established as soon as the latency becomes short. But how low the response rate in ITI should be before we say that the discrimination is established is an arbitrary decision. Even if statistical methods were introduced to determine such a point, the decision is still arbitrary. Yet, there can be little doubt that the stimulus control is nearly fully established by the end of the session. Often decisions about when behavior control is established is a practical affair used to reach a consensus among researchers or clinicians. For example, one might for such practical purposes decide that the discrimination is established when the latency is consistently less than 5 s for 10 consecutive trials with no more than a single response during each ITI for those trials. However, in some cases of application of stimulus control, such as using animals for search and rescue, report responses during periods with no stimulus, called "errors" or "false alarms," can be very critical. Similarly, failure to respond to the stimulus can have devastating consequences if the stimulus, for example, is explosive material that the animal is trained to detect (e.g., Poling et al., 2011). Thus, for application, it is essential to train to optimal performance of consistent and quick responding to the stimulus, and consistent absence of the response when the stimulus is absent, as illustrated in the after-discrimination display in Figure 1 and section C in Figure 3.

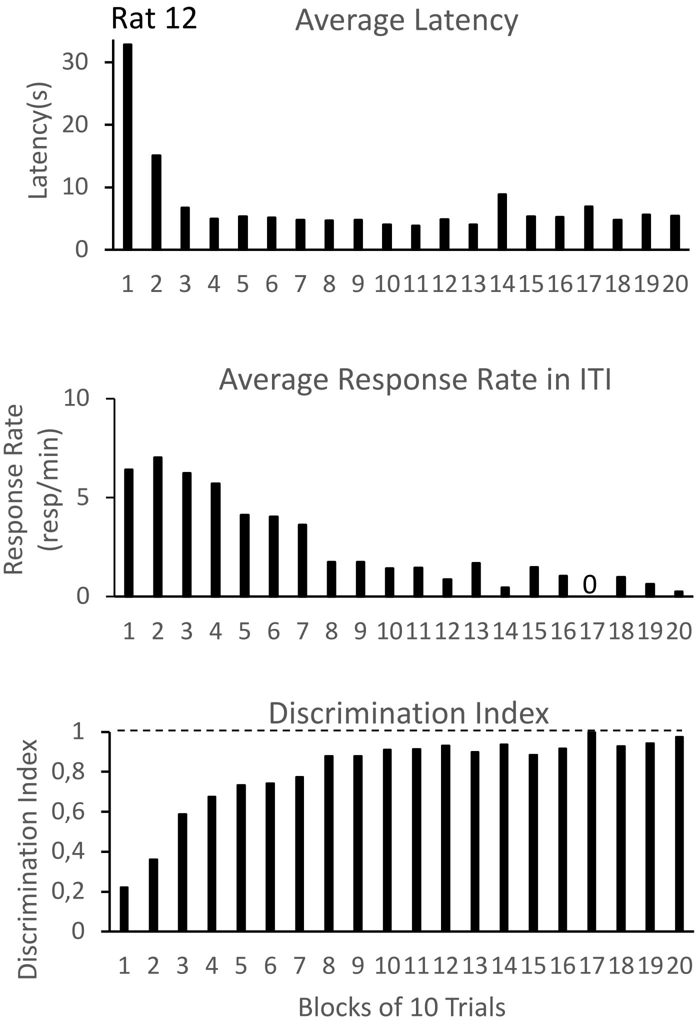


Figure 4. Average latency, response rate in ITI, and discrimination index for Rat 12, in blocks of 10 trials for the session depicted in Figure 2.

Note. Blocks of 10 trials for the whole session shown in Figure 2 were averaged for latency, response rate in ITI, and discrimination index. This index is calculated as the rate of response in trials (the light) over the sum of response rate in trial and ITI periods. The value varies from 0 to 1, with 1 signifying perfect discrimination with all responses to trials and none during ITI periods. Data are for rat 12.

### Stimulus Control in Real Time

Once one has decided that stimulus control is established, from that point on one can with confidence predict that whenever one turns the stimulus on, the response will follow promptly. And we can be equally confident in stating that the response is fully or almost absent when the stimulus is absent. So, while it will require several trials to determine or infer that the discriminated operant is established, we can on the other hand use that information at the single trial level in the future to be able to predict the behavior in real time and thereby, in fact, control the behavior by providing the stimulus, "here and now" — so to speak. Obviously, this aspect of the discriminated operant, that it can be defined to occur at the level of the individual trial, is essential for implementation of stimulus control procedures in application of behavior analysis methods (Cooper et al., 2019). Equally important is the fact that to establish the discriminated operant, the three-term contingency must operate at each trial from the very beginning. Thus, in application, as well as in the laboratory, it is essential that the response is reinforced when it occurs in each identifiable single trial and that it is not reinforced when it occurs at other times. Thus, the conceptual side of acquisition of stimulus control passes through several stages or levels of analysis, from the initial single-trial implementation in training, through consensual identification of established control that may require several trials for confirmation, through actual control of the behavior at the level of individual trials (just as when the acquisition process began). In the end, you can control behavior in real time by presenting the stimulus. And each successful occurrence of such control confirms the conclusion reached earlier that the procedure had established stimulus control.

### Conditioned Reinforcement and Chaining

After operant discrimination has formed, one can demonstrate that the stimulus itself has acquired reinforcing properties (Skinner, 1938). How is this demonstrated? To demonstrate that "something" can function as a reinforcer, then one presents this "something" as a consequence to some arbitrary response. If the response increases in frequency, then the conclusion is that this something functions as a reinforcer for the response. As for the discriminated operant, to demonstrate that the stimulus or $S^D$ has become reinforcing one needs to make presentation of the $S^D$ contingent on a response that is different from the response that is controlled by the presentation of the $S^D$. A novel response, in the present case pressing the left lever in the Skinner box, was arranged to turn on the light, and when the light was turned on the procedure was the same as before; the first response to the right lever produced the food pellet and terminated the light. The next response on the left lever turns on the light, and so on. The timed presentation of the $S^D$ during acquisition is suspended, and the length of the ITI is now determined entirely by the rat, as pressing the left lever starts the trial and ends the ITI. One session following the session described above was arranged to demonstrate such a "chain" of behavior: press the left lever, the light turns on, then press the right lever, and the pellet is delivered (and the light turns off). An additional arrangement for the second session was that the number of responses to the left lever would be increased by one unit for each passing of 20 reinforced trials. After 80 reinforcers the procedure changed to extinction such that the left lever press did not turn on the light, and no more trials occurred that session.

Figure 5 shows the cumulative record of pressing the right lever for this second session. Presses on the left lever are shown on a trace right above the trace for the stimulus (the labels R, L, and S, refer to right lever, left lever, and stimulus presentation, respectively). Presses on the left lever had occurred sporadically during the first session but had no consequences other than being recorded. Thus, it was expected

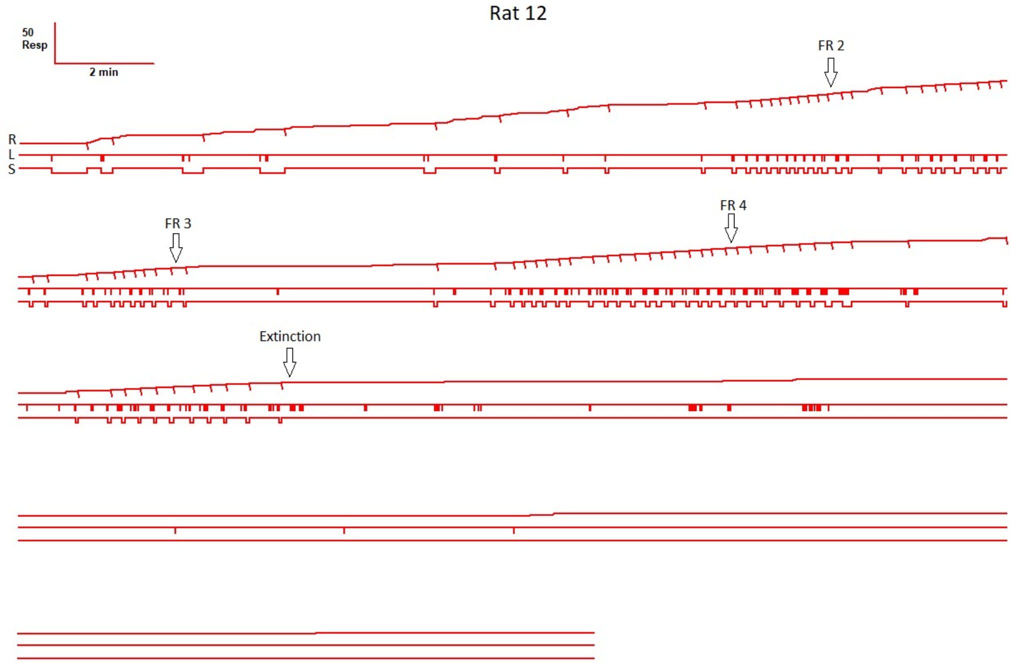


Figure 5. Conditioned reinforcement test.
Note. Cumulative record of pressing the right lever (R), event record of pressing the left lever (L), and event record of stimulus presentation (S). Reinforcer presentation indicated by marks on the response pen. Pressing the left lever turned the stimulus on and pressing the right lever during the stimulus produced a food pellet. The number of presses required on the left lever was increased by one for each 20 reinforced trials, as indicated by values of FR (fixed ratio). After 80 trials, the procedure changed so that the pressing the left lever did not turn on the stimulus, as indicated by Extinction.

that the rat would at some point press the left lever. That happened almost from the beginning of the session, and the rat then pressed the right lever during the stimulus and produced reinforcement. For the first 10 trials, right lever presses return to some extend during the ITI, but after about 10 trials the right lever responses are almost absent during the ITI for the remainder of the session, and the rat presses the left lever promptly shortly after reinforcement. In addition, the reaction time to the stimulus becomes very short and remains short for the remainder of the session. The rat makes a long pause after the requirement for the left lever is increased to three responses. When extinction was installed, the left lever is pressed 49 times before the session is terminated. Only 8 right-lever responses occurred during extinction. The latencies during the chaining procedure are shorter and consistently so compared to the pure discrimination procedure from the first session (e.g., Figure 2). The average latency for the last 20 trials of session one was 5.48 s with a standard deviation of 3.1 s, but for session two with the chaining procedure, the average latency for the last 20 trials was 3.16 s with a standard deviation of 1.87 s. Clearly the latency was shorter in the chaining procedure and showed considerably less variability, as was evident on the cumulative record in Figure 5. Such a finding has been noticed very often in this laboratory with similar procedures. Direct observations indicate that during normal discrimination procedures the rat may be at different locations in the Skinner box when the light turns on (and may travel different distances or may have its back to the light or may be grooming when the light turns on or may have the head inside the food tray – these different behaviors may lead to different latencies). With the chaining procedure, the rat is always at the exact same location when the light turns on, and that is at the location of the left lever because the left lever press turns on the light. Thus, the travel distance is always the same and the rat is always oriented the same, hence the shorter and less varying latency.

The demonstration of establishment of a simple chain of behavior without direct reinforcement of the first response by the primary reinforcer (the food) opens for discussion how a novel response can be strengthened by arranging a contingency so that it turns on the discriminative stimulus. The finding illustrates that the discriminative stimulus has two properties. First, it serves as a discriminative stimulus for one response, the right lever press, but it also has a reinforcing property for another response, the response that turns it on (i.e., the left lever press in this case). The discriminative properties of a stimulus are assessed during the stimulus (i.e., a response occurs when the stimulus is turned on). On the other hand, the reinforcing properties of a stimulus are assessed during the period prior to the stimulus. The literature of stimulus control refers to this finding as the dual role of a discriminative stimulus (Keller & Schoenfeld, 1950). Thus, the discriminative property of a stimulus is assessed in its presence, the $S^D$, whereas the reinforcing property of a discriminative stimulus (the $S^D$) is assessed in its absence, during the $S^\Delta$. The reinforcing function of a discriminative stimulus if often referred to as conditioned reinforcement; the stimulus itself is not a reinforcer but when the stimulus becomes a discriminated operant it acquires reinforcing properties, hence the term conditioned reinforcement (Catania, 2017; Keller & Schoenfeld, 1950).

**Replication**

This demonstration featured just a single rat. Each semester in the undergraduate laboratory course on operant conditioning, the experimental sessions are from half an hour to at most one hour, and several sessions are necessary to establish a solid discrimination. However, with the method used here of a single, long session, discrimination can easily be established with 200 trials or less. Yet, replication is the hallmark of science (Iversen, 2013). To determine if the results of the present method are general, a second subject, Rat 11, was placed on the same procedure as Rat 12. The session had to be cut short at 130 trials because of a fault in the equipment. The rat was then given another 100 trials the next day before given the test on chaining as for Rat 12. The overall performance of Rat 11 was very similar to the performance of Rat 12. Figure 6 shows for Rat 11 the averages for latency, response rate in ITI, and discrimination index for the session with 130 trials. The overall pattern is the same as for Rat 12 with latencies quickly decreasing to a very short value. However, the response rate in ITI reduced more slowly than for Rat 12. Correspondingly, the discrimination index rose more slowly for Rat 11 but reached almost 0.9. The third session with the chaining procedure had a result very similar to that for Rat 12. Eighty trials were completed and, as for Rat 12, the latencies became shorter and much less variable (average latency and standard deviation for the last 20 trials for the first session was 3.59 s and 1.98 s, respectively; for the last 20 trials of the chaining session these values were 1.73 s and 0.54 s). Thus, the data for both rats are very similar in showing that the discriminative stimulus not only controlled the right lever response but could also serve as a conditioned reinforcer for a novel response. In addition, the replication confirmed that the latency to the stimulus was much shorter and varied considerably less with the chaining procedure than with the regular procedure without chaining.

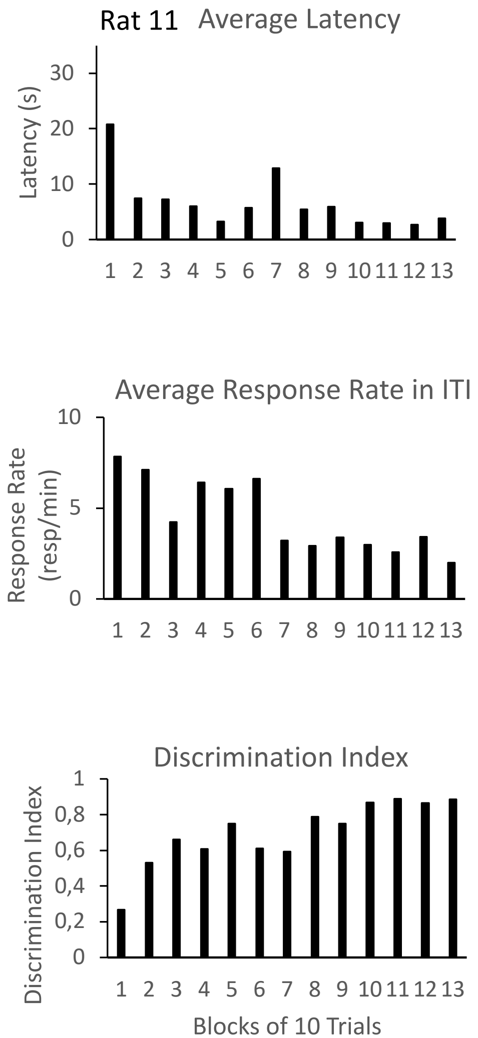


Figure 6. Average latency, response rate in ITI, and discrimination index for Rat 11, in blocks of 10 trials.

Note. Data analysis and procedure are the same as for Rat 12. See note for Figure 4. Data are for Rat 11. Only 130 trials were scheduled for the session displayed.

## Conclusion

In the animal laboratory, undergraduate students who have established a clear discriminated operant almost invariably exclaim: "our rat is so smart, it understands what it has to do". On the other hand, some rats on occasion need more training than time allows for, and those rats may make too many responses during ITI or have a slow reaction to the stimulus. The students who have such a rat often say that "we got the dumb rat, or how come our rat does not understand the procedure." In both cases, terms like smart or dumb and "understanding" are used as some sort of explanation that is entirely parallel with the observed behavior. One does not say that the rat understands the procedure if it responds poorly, and vice versa if the rat responds well, as expected, you do not say that the rat does not understand the procedure. Thus, such terms are essentially superfluous. In addition, if used, terms like "understanding" often become explanatory variables inserted by the observer between the independent variable, here the repeated exposure to the three-term contingency, and the dependent variable, here a short latency to the light and low response rate during the ITI. Even Thorndike (1911) stated for laws of behavior to be useful or scientific that after learning: "Behavior is predictable *without recourse to magical agencies.*" (p. 241; emphasis by Thorndike). Skinner (e.g., 1953) similarly repeatedly articulated that a science of behavior need not refer to the "inner man" as an explanatory agent. In a science of behavior, behavior can be dealt with entirely with respect to how the organism interacts with the environment. Thus, even as simple a demonstration as acquisition of stimulus control of a lever press by a light can further discussion of various ways of interpreting or dealing with behavior changes. Even after students have witnessed the actual process of acquisition of stimulus control in front of their eyes, many still feel that there is something "missing" in the explanation. For some students, they begin to appreciate the core of behavior analysis at this point when it is pointed out to them that the term "understanding" is an invented term that they did not control in the experiment and that this or similar terms are entirely unnecessary in a science of behavior. A simple visual comparison of the beginning of the cumulative record in Figure 2 with the traces toward the end show that the rat's behavior obviously changed during the 2 hr of repeated exposure to the three-term contingency. Thorndike (1911) recognized this issue and stated that if the organism responds differently to the same stimuli then the organism must have changed. Skinner (1953) stated that the individual organism's history of (or past exposure to) contingencies of reinforcement are responsible for the changes in behavior.

Skinner (1953) expressed the various implications of environmental control of voluntary behavior in great nuance and detail in his *Science and human behavior*. Here is at some length how Skinner (1953) articulated the broader applications and implications of the discriminated operant established through the three-term contingency.

> The social environment contains vast numbers of such contingencies. A smile is an occasion upon which social approach will meet with approval. A frown is an occasion upon which the same approach will not meet with approval. … The ringing of a telephone is an occasion upon which answering will be followed by hearing a voice. The young child may pick up and speak into the telephone at any time, but eventually he will do so only when it has been ringing. The verbal stimulus "Come to dinner" is an occasion upon which going to a table and sitting down is usually reinforce with food. … Bells, whistles, and traffic signals are other obvious occasions upon which certain actions are generally followed by certain consequences. Verbal behavior fits the pattern of the three-term contingency and supplies many illuminating examples. We learn to name objects by acquiring an enormous repertoire of responses each of which is appropriate to a given occasion. A chair is the occasion upon which the response "chair" is likely to be reinforced, a cat is the occasion upon which the response "cat" is likely to be reinforced, and so on.… The three-term contingency is evident in teaching a child to read, when a given response is reinforced with "right" or "wrong" according to the presence of absence of the appropriate visual stimulus. (p. 108–9).

Thus, the demonstration of acquisition of stimulus control in the animal laboratory is a relatively simple procedure that can serve as a gateway for considerable discussion about the core of behavior analysis and the scientific approach to behavior. The demonstration also prompts broader discussions of stimulus control and applications of stimulus control procedures in clinical and educational environments. After having participated in this research, plotted the data, and discussed the outcome and implications, most students will see the broader value of this relatively simple demonstration of teaching a rat to press a lever when a light turns on.

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