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On the dynamics of stimulus control during guided skill learning in nonhumans☆

Alliston K. Reid*, Nathan Folks, Jordan Hardy

Department of Psychology, Wofford College, Spartanburg, SC 29303, USA

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ABSTRACT

This study measured skill acquisition in the presence and absence of guiding cues in pigeons.

It asked whether the speed of development of autonomy for the motor skill is influenced by the difficulty level of two guiding-cue conditions requiring the same left–right response sequence. The Follow-Red condition required a simple go, no-go discrimination (red = S+, green = S−), whereas the Red–Green condition was a more difficult simultaneous chain requiring sensitivity to the serial order of key colors (red = S+, green = S− for the first peck, but red = S−, green = S+ for the second peck). Pigeons exposed to the difficult Red–Green condition displayed significantly higher accuracy levels during no-cues conditions earlier in training than those exposed to the easier Follow-Red condition. A modified Power Law of Practice was used to evaluate the null hypothesis that autonomy develops equally in explicit guiding-cues conditions and no-cues conditions. This hypothesis was retained in the Follow-Red condition but rejected in the Red–Green condition. Practice completing the response sequence in the Follow-Red and no-cues conditions both contributed equally to autonomy. Autonomy developed faster in the Red–Green group in both conditions, and it developed unexpectedly rapidly during the second guiding-cues condition, implying the involvement of a second process for the Red–Green condition. We discuss the implications of these results to prompt dependence in children with learning disabilities, the transfer of stimulus control, and potential behavioral interventions.

1. Introduction

There are many ways of conceptualizing behavior patterns. Research in this lab has focused on the rules of integration of environmental cues and responses to produce adaptive patterns of behavior. Behavior analysis has a long tradition of conceptualizing heterogeneous behavior patterns as behavior chains, in which each response in the chain is presumed to be controlled by a discriminative stimulus, and response-produced stimuli both reinforce that response and "set the occasion" for the next response.

1.1. *Stimulus control in motor skills*

In a series of experiments, Reid et al. (2010) and Reid et al. (2013b) expanded this view of behavior chains by arguing that behavior chains in nonhumans are often equivalent to motor skills in humans. Most people recognize the impressive skills demonstrated by dogs in agility training, dolphins and sea lions performing in amusement parks, and the many videos of trained animals available on online sources. Animal training is an art of applying known principles of learning and behavior. The typical focus is on the role of reinforcement on behavior patterns, but we focus on the role of stimulus control in the acquisition of a motor skill for two reasons. First, rats and pigeons are sometimes remarkably insensitive to informative stimuli that should, on face value, come to control responding (Fox et al., 2014; Reid et al., 2013b). Second, children with autism or severe learning disabilities often show "prompt dependence". They fail to learn to produce these skills independently, without continued prompts provided by the instructor. Prompt dependence describes the failure of stimulus control to transfer from the teacher's prompt (now say "Thank you") to control by situational cues (such as receiving a gift) (MacDuff et al., 2001). Foundational research about changes in stimulus control and cue interaction during skill learning should lead to deeper

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* Corresponding author at: Department of Psychology, Wofford College, 429 North Church Street, Spartanburg, SC 29303, USA. Tel.: +1 864 597 4642;
fax: +1 864 597 4649.
E-mail address: reidak@wofford.edu (A.K. Reid).

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understanding of the development of skill learning, the causes of prompt dependence, and may help to suggest improved behavioral interventions.

1.2. Two sources of stimulus control

Reid et al. (2010) emphasized how skill learning in rats requires a change in stimulus control. At least two sources of stimulus control are involved: environmental events from instructors or lights in a Skinner box, and "practice cues" that result from the subject's own behavior of repeating the same response pattern (Lattal, 1975; Shimp, 1981, 1982). As the skill is acquired, reliance on (or control by) practice cues increases until the behavior pattern can be performed correctly and efficiently in the absence of explicit guiding cues. High accuracy in the absence of the previous guiding cues is commonly called "autonomy" – the autonomous skill now controlled by newly-developed practice cues. The important role of practice in skill learning has long been recognized in cognitive psychology even before Ebbinghaus (1885), but the variable of interest has often been the number of practice trials, rather than practice cues. Behavior analysis has much to offer to improve understanding of skill learning. It allows us to clearly identify and control practice cues; it provides procedures for measuring the quantitative changes in control by environmental events and developing practice cues as motor skills are acquired; and it allows the measurement of cue interaction. These are the goals of the current experiment.

1.3. Measuring practice cues and autonomy

Two conditions in Reid et al. (2010) provide a useful means of defining the terms and skills used in the current study. Rats first learned to "follow the light," and then we removed the lights to assess how well they could complete the task without external guidance (i.e., their degree of autonomy). The 'skill' to be acquired by rats was a left–right (L–R) lever-press sequence in a discrete-trials procedure. The 'guiding cues' were the presence and absence of panel lights over the respective levers. At the beginning of each trial in the 'follow-the-light' condition, the panel light over the left lever was illuminated, whereas the light over the right lever was off. A press to either lever caused the left light to turn off and the right light to turn on. A second press terminated the trial. No feedback was provided within the trial about response accuracy. The L–R sequence produced a food pellet, whereas all other sequences produced timeout with the lights off. This response sequence was required in all conditions. Eleven rats were exposed to this condition until L–R sequence accuracy exceeded 80% with no increasing or decreasing trends for five consecutive sessions. Once a rat achieved this accuracy-stability criterion, it was exposed to a 'no-lights' condition in which both panel lights remained off, eliminating the panel lights as cues to guide response selection with the trial. The high 90% accuracy during the follow-the-lights condition dropped to about 50% in the no-lights condition. Thus, rats were able to complete the correct L–R sequence about half the time without the lights guiding response selection. We assumed that their behavioral history of repeating the same L–R sequence hundreds of times allowed the development of "practice cues" that were able to guide response selection at 50% accuracy. Different rats required different numbers of sessions to reach our stability criteria. This allowed us to examine the size of the drop as a function of the number of training sessions (ranging from 9 to 22 sessions). We observed an approximately linear relation: more training led to a greater ability to complete the sequence without the cues. We called this a "practice effect," which demonstrated the development of practice cues. More practice completing the sequence led to greater autonomy, which we defined as the acquired ability (measured by accuracy level) to complete the sequence correctly without the lights as cues. Different amounts of training led to different accuracy levels, thus different degrees of autonomy.

Subsequently, Reid et al. (2013b) repeated this basic procedure with training on a more challenging "reversed-lights" guiding-cue condition (Expt. 2). In this case, light off was S+, and light on was S−, reversing the cues from Reid et al. (2010). The motor skill was the same L–R response sequence as before. This training condition required about twice the number of sessions for rats to reach the same accuracy-stability criteria as before, 28 sessions as compared to 14. When switched to a no-cues condition that eliminated the lights as guiding cues, accuracy dropped only 20–25%. Consistent with the idea of developing practice cues, more practice with the L–R sequence led to higher accuracy, i.e., more autonomy.

1.4. Cue interaction

Both of these studies provided important clues about the nature of cue interaction. Do explicit guiding cues and practice cues interact the same way as in Pavlovian conditioning? If behavior first becomes controlled by explicit cues (the panel lights as discriminative stimuli) and practice cues only develop later, should we not expect to observe blocking of practice cues? Both studies demonstrated that practice cues developed while explicit guiding cues were provided, and more exposure to the guiding cues led to improved accuracy in the presence and in the absence of these cues. Reid et al. (2013b, Expt. 3) demonstrated that acquisition of the response sequence is delayed considerably when guiding cues are not provided. These studies tentatively imply that explicit guiding cues facilitate the acquisition of practice cues, rather than compete with them for control of behavior.

Imagine the following scenario. You have moved to a new university, and you want your young child to learn how to walk from the parking lot to your new office. Which would promote faster autonomy for your child: to "lead him or her by the hand" as you walk along each sidewalk, or by providing less guidance such as asking at each corner "which way do we go?" Reid et al. (2013a) asked whether the development of control by practice cues is influenced by the degree of "effectiveness" of stimulus control by explicit guiding cues, with some cues being more effective at controlling behavior than others. Accuracy may always be high if you "lead the child by the hand" as the task is completed, but such direct guidance may not lead to faster autonomy. They also suggested that prompt dependence may reflect this failure for the task to become controlled adequately by other cues.

Following the demonstration by Reid et al. (2013b) that the lights and reversed-lights conditions differed reliably in their effectiveness as guiding cues, Reid et al. (2013a) asked whether control by guiding cues and practice cues develop at the same rate, and whether the effectiveness of guiding cues (Lights versus Reversed-Lights) influenced this rate. One group of rats acquired the L–R sequence exposed to the Lights condition, and another group was exposed to the Reversed-Lights condition. We measured developing stimulus control by guiding cues and by practice cues independently in the same sessions by inserting probe trials without guiding cues. We found that while the Lights condition produced greater accuracy when those cues were provided, the development of practice cues was retarded, with autonomy remaining low even after 36 sessions. Nevertheless, in the (less effective) Reversed-Lights condition, control by practice cues was approximately equal to control by guiding cues across all 36 sessions. In this condition, control by both types of cues appeared to develop at approximately the same rate. In terms of the analogy, holding your child's hand too much seems to slow the development of autonomy.