Understanding Operant Behavior: Still Experimental Analysis of the Three-Term Contingency

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Killeen and Jacobs (2017) argue that Skinner's three-term contingency (discriminative stimulus-response-reinforcer) cannot fully describe behavior until a fourth term is added to represent the organism. Such a term is necessary because, for example, the same stimulus sometimes functions as a reinforcer and sometimes does not, depending on the state of the organism. We argue, instead, that the three terms of the traditional contingency should be treated as variables, not as constants. Then a systematic experimental analysis can be conducted to determine the factors that control each of those variables. We describe such an analysis of the factors that govern the effectiveness of reinforcers. We argue that such an approach is simpler and more parsimonious, but also more theoretically fruitful and practically useful, than the proposal of Killeen and Jacobs. Our analysis suggests that the three-term contingency, to which Killeen and Jacobs object, is not empty or exhausted. Instead, the contingency, when coupled with an experimental analysis, is still the best way to theoretically understand and to practically control behavior and therefore the best way to generate useful and accurate theories of behavior.

In this paper, we will describe findings about the variables that alter the effectiveness of reinforcers. These findings come from our own, and other, laboratories and we use them as an example only because they are familiar to us. Many other investigators have studied the factors that govern the effectiveness of the discriminative stimulus, response, and reinforcer. The present paper will provide only a cursory description of our own findings, an exhaustive account of which may be found in McSweeney and Murphy (2014).

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We will start by describing the basic empirical finding. Then, we will describe the experimental analysis that we performed to understand that finding. We will show how our analysis can be used in practice to understand and control behavior and we will show how our analysis leads to theoretical advances. The reader can judge whether this approach, or that offered by Killeen and Jacobs (2017), provides the more useful and accurate understanding of behavior. We apologize to those who are already familiar with this work. This article will be repetitious for you.

The Empirical Finding

We have reported that the rate of operant responding is not constant within an experimental session even when the conditions of reinforcement are constant across that session (McSweeney, 1992; McSweeney & Hinson, 1992). Instead, at rates of reinforcement often used in operant experiments (e.g., 60 reinforcers/h), response rate often increases and then decreases across the course of, say, a 60-min experimental session. The decrease in response rates may also occur without the increase and vice versa. Decreasing response rates are usually observed when high rates of reinforcement (e.g., 240 reinforcers/h), and when no reinforcers (extinction), are provided. Response rate may be constant across the session at low rates of reinforcement (e.g., 6 reinforcers/h). These within-session changes in responding are large and occur in a steady-state behavior. That is, they are not acquisition curves. They are highly general, occurring for many species (e.g., rats, pigeons, and humans), procedures (e.g., free operant and discrete trials), and reinforcers (e.g., food, drugs, lights, and conditioned reinforcers), and they have been reported by several laboratories in addition to ours (e.g., Aoyama, 2000; Ernst & Epstein, 2002; Lloyd, Gancarz, Ashrafioun, Kausch, & Richards, 2012; Morewedge, Huh, & Vosgerau, 2010).

The Experimental Analysis

Reinforcer Delivery Produces the Changes in Responding

We and our collaborators tested many potential hypotheses to explain these within-session changes in responding. We found that the within-session changes are not produced by the act of responding (e.g., muscular warmup, fatigue), by variables associated with the passage of time in the session (e.g., recovery from handling, anticipation of the end of the session), by changes in interfering responses (e.g., exploration of the chamber, falling asleep), by changes in a general motivational state (e.g., arousal), or by several cognitive variables (e.g., focusing, waning of attention).

To give one example, if the act of responding produced the within-session changes in responding, then changing the nature of the response (e.g., its difficulty) should change the within-session response pattern. Also, the size of within-session changes should be reduced if responding is prevented temporarily. These predictions were not confirmed (see McSweeney & Murphy, 2014). Therefore, we rejected the idea that factors related to responding cause the within-session changes in responding.

Instead, within-session changes in responding are produced mainly by systematic changes in the effectiveness of the reinforcer with its repeated delivery. That is, changes in the rate and nature of reinforcement systematically change the form of the within-session response patterns. Probe preference tests, a generally accepted measure of reinforcer effectiveness, also change systematically with the repeated delivery of the reinforcer in the session (e.g., McSweeney, Weatherly, & Swindell, 1996).

Sensitization and Habituation to the Reinforcer Change Reinforcer Effectiveness

Many further studies showed that changes in the effectiveness of the reinforcer were mainly produced by sensitization and habituation to the sensory properties of the reinforcer with its repeated delivery. Within-session changes were not produced by the intuitively-more-popular variable, satiation to the reinforcer (see reviews by McSweeney, 2004; McSweeney & Murphy, 2000; McSweeney & Roll, 1998). Habituation is a decrease in responsiveness to a stimulus that is presented repeatedly or for a prolonged time (Thompson & Spencer, 1966). Sensitization, the companion process of habituation, is an increase in responsiveness to a repeatedly presented stimulus (Groves & Thompson, 1970). Sensitization often, but not always, precedes habituation.

The many properties of habituation are well understood (e.g., Rankin et al., 2009) and provide a strong operational definition for establishing its presence (e.g., Thompson & Spencer, 1966). Therefore, the hypothesis that sensitization-habituation produces the within-session changes in responding could be, and was, tested extensively. We will describe only five of the tested properties of habituation here. We have chosen the first property because it explains the effect of deprivation for the reinforcer, perhaps the most widely acknowledged motivating operation that alters reinforcer effectiveness. We have chosen the other four properties because they lead to surprising predictions that are particularly useful in separating habituation from alternative explanations for the within-session changes in responding. All of these surprising properties, and most of the other properties, of habituation have been found for within-session changes in responding, yielding strong support for this hypothesis (McSweeney & Murphy, 2014). Here are five properties of habituation and their definitions.

Spontaneous recovery—Responding to a habituated stimulus recovers in the absence of that stimulus.

Dishabituation—Presenting a strong, different, or extra stimulus restores responsiveness to a habituated stimulus.

Stimulus specificity—Habituation is disrupted by unpredicted changes in the stimulus.

Variety effects—Habituation occurs more slowly to stimuli presented in a variable, rather than a fixed, manner.¹

¹ Variety effects and stimulus specificity may be two different procedural ways to manipulate the same variable. They may both disrupt habituation (or introduce sensitization) by providing unpredicted changes in the stimulus. The changes in the stimulus may be introduced periodically in the session (a violation of stimulus specificity) or they may occur continuously throughout the session (a variety effect).

Stimulus intensity—The weaker the stimulus, the more rapid and pronounced the habituation.

Regulating the Effectiveness of a Reinforcer in Practice

The results of this experimental analysis lead to some surprising implications for applied behavior analysis. These implications are discussed in Murphy, McSweeney, Smith, and McComas (2003) in more detail. We will only briefly review them here.

Sometimes behavior analysts wish to strengthen a reinforcer that is too weak to maintain appropriate behavior. For example, repeatedly presented food may eventually lose its ability to reinforce the behavior of a child with autism. Other times, behavior analysts wish to weaken a reinforcer that is maintaining too much behavior. For example, food reinforcers may maintain too much eating for obese clients. The present analysis suggests that the behavior analyst working with the child with autism could maintain the strength of food by decreasing habituation and/or increasing sensitization to those reinforcers. The behavior analyst working with obese client could weaken the strength of food as a reinforcer by increasing habituation and/or decreasing sensitization to food. Here are some suggestions about how to achieve those goals that follow directly from our knowledge of the properties of habituation.

1. Change deprivation—Spontaneous recovery implies that a reinforcer that has lost its effectiveness through habituation will recover if time is allowed to elapse in the absence of that reinforcer. That is, habituation decreases with increasing deprivation for (time without) the reinforcer. The behavior analyst working with the child with autism should make sure that sessions are well spaced, that reinforcers are presented infrequently within sessions, and that the session is paused for some time whenever the effectiveness of the reinforcer wanes. These predictions are not surprising and are consistent with the literature on motivating operations.
2. Control strong, extra, or novel stimuli—Dishabituation implies that habituation may be disrupted when strong external stimuli are introduced. Therefore, the behavior analyst who wishes to maintain the effectiveness of food as a reinforcer for a child with autism should work in an environment that is filled with unpredictable stimuli. The behavior analyst may want to maintain control over those stimuli by providing them for him- or herself, but that is not necessary for this analysis to work. Stimuli provided by other children, other behavior analysts, others outside of the laboratory, etc. should be just as effective as experimenter-controlled stimuli in restoring the effectiveness of waning reinforcers. Conversely, the behavior analyst working with the obese client should encourage that client to eat in relatively quiet and constant environments. The client should not eat while watching television or listening to music. The client should avoid noisy cafeterias and eat alone if possible. These predictions do not follow obviously from most other theories of reinforcer effectiveness, or by adding the fourth-term, O, to the

traditional three-term operant contingency as proposed by Killeen and Jacobs (2017).

3. Control changes in the reinforcer—Stimulus specificity implies that habituation is disrupted by changes in the reinforcer. Therefore, when food is losing its effectiveness as a reinforcer, the behavior analyst should change the delivered food or the conditions of its delivery. For example, if candy is the reinforcer, M&M's could be changed to Snickers then to Butterfingers, etc. each time the current reinforcer weakens. Periodically changing the size, color, shape, conditions of delivery, etc. of the reinforcer should also help to maintain its effectiveness. Conversely, the behavior analyst working with an obese client should encourage the client to eat only a limited number of different foods. For example, diets that restrict consumption to only one or a limited number of foods become popular from time to time. Many people believe that the reason that, for example, a grapefruit diet may work is that eating grapefruit provides few calories. If the present argument is correct, though, it may be the monotony of these diets, not their restriction of calories, that make the diets effective. According to our thinking, a strict diet of cheese cake should also encourage weight loss because habituation will quickly reduce the ability of cheese cake to reinforce consumption.² The behavior analyst might also urge the client to avoid meals with lots of different courses. The client will eat less in a meal with only one or two courses, each of which provides different foods, than in a meal with more different courses. The consumption differences will occur even if equal total amounts of food are offered by the two types of meals. Again, these predictions do not follow obviously from most other theories, including Killeen and Jacobs' (2017) proposal.
4. Control the variety of reinforcers—Variety effects imply that introducing variety into the reinforcer from the start of the session should also help to maintain the effectiveness of those reinforcers. For example, the frequent choice of M&M's (or Skittles) as reinforcers in applied work may not be accidental. Instead, the changing color of the candy from reinforcer to reinforcer may itself help to maintain reinforcer effectiveness through variety. In addition, a behavior analyst who wishes to maintain the effectiveness of candy as a reinforcer might sometimes provide M&M's, sometimes Snickers, sometimes Butterfingers, etc. as the reinforcer for the behavior of a child with autism. In contrast, a behavior analyst trying to weaken the effectiveness of food as a reinforcer for an obese client should urge the client to avoid buffets. People should consume more food when eating at buffets than when eating a standard meal because the buffet provides an alternative effective food each time the effectiveness of one food wanes through its consumption. Again, these predictions are not anticipated by most other theories, including Killeen and Jacobs' (2017) proposal.
5. Control stimulus intensity—Behavior analysts who wish to maintain the effectiveness of food for a child with autism should deliver a high intensity

² The cheese cake diet is suggested only to illustrate a prediction of the present analysis. In practice, no one should undertake a diet that provides such a limited variety of needed nutrients.

food as the reinforcer. Habituation will occur more slowly to high, than to low, intensity foods. So, for example, a carbonated beverage that contains a large sugar concentration should retain its effectiveness longer than a soft drink with a lower concentration of sugar. Conversely, a behavior analyst working with an obese client could urge the client to eat only less intense foods by, for example, limiting the use of salt and spices. Again, these predictions do not follow from most other theories, including Killeen and Jacobs' (2017) proposal.

The reader may doubt some of these predictions because they seem so counterintuitive, but McSweeney and Murphy (2014) provide a review of the laboratory findings that support each of these claims. Some of these studies were conducted with food reinforcers and human participants (see work by Epstein and his colleagues, e.g., Ernst & Epstein, 2002). In addition, Barbara Rolls' work on stimulus-specific satiety shows that these effects on the consumption of food by human participants are real and can be quite large (e.g., Rolls, Rowe, & Rolls, 1982).

Theoretical Insight

The results of this empirical analysis can also provide theoretical insights. As argued by McSweeney and Murphy (2014), this analysis has theoretical implications for several operant phenomena including the matching law (McSweeney & Murphy, 2014), extinction (McSweeney & Swindell, 2002), and behavioral contrast (McSweeney & Weatherly, 1998). Surprisingly, experiments to date show that sensitization-habituation does not explain the often observed preference for variable reinforcers (McSweeney, Kowal, & Murphy, 2003). Such a preference seems to be a straightforward prediction of variety effects. That is, variable reinforcers should maintain their effectiveness longer than constant reinforcers and therefore be more strongly reinforcing when averaged over a session, because variable reinforcers produce less habituation than constant reinforcers. The present experimental analysis can also provide insights into theoretical phenomena beyond the operant field including several phenomena in the classical conditioning literature (McSweeney & Murphy, 2014) and the literatures on habituation (Rankin et al., 2009), behavioral pharmacology (McSweeney, Murphy, & Kowal, 2005), and motivation (McSweeney & Swindell, 1999).

Here is one example of how this experimental analysis suggests answers for fundamental theoretical questions. We will use motivation as this example because Killeen and Jacobs (2017) urge us to add motivation to our theoretical analysis, but provide little guidance on how to do that. In contrast, McSweeney and Swindell (1999) argue that the present analysis explains many of the puzzling findings in the literature on motivation. They argue that the goal objects of motivated behaviors serve as reinforcers and that animals sensitize and then habituate to those reinforcers with repeated contact. These ideas explain the waxing and waning of behaviors that is often taken as a sign of

changing motivation for those behaviors. To quote their abstract, “Several characteristics of motivation are consistent with this idea. Motivated behaviors decrease in strength with contact with the goal (habituation) and increase in strength in the absence of the goal (spontaneous recovery). They may increase in strength with initial contact with the goal (sensitization precedes habituation), with the presentation of irrelevant stimuli (sensitization), with changes in the goal (stimulus specificity) and with the presentation of dishabitators (dishabituation).” (p. 437).

For example, McSweeney and Swindell (1999) argue that this theory explains why presenting irrelevant stimuli strengthens motivated behaviors. Bolles (1980) described the finding that rats eat more after their tails are pinched, than when they are not pinched, by writing, “Consider tail-pinch as a source of eating. It is an interesting phenomenon precisely because it does not make much sense; it is an exception to the rule that motivational systems are well-adjusted and independent.” (p. 229). McSweeney and Swindell attribute this finding to dishabituation (or sensitization). That is, presenting a strong, irrelevant stimulus, such as a tail pinch, reduces habituation and strengthens the ability of food to reinforce its own consumption. They argue that, “The fact that our argument anticipates such facilitation provides relatively strong support for it. Past theories of motivation have left this facilitation unexplained.” (p. 445).

In addition, McSweeney and Swindell’s (1999) argument helps to explain the puzzling finding that motivated behavior shows the same characteristics regardless of whether the goal object is a biologically important stimuli (e.g., food, water, sex) or a stimulus that seems arbitrary (e.g., money, gambling, shopping). The similarity of behavior directed at these different goals follows from McSweeney and Swindell’s argument because sensitization-habituation may occur to any stimulus that functions as a reinforcer, regardless of whether the stimulus is biologically important or not.

Potential Response to This Argument

We suppose that Killeen and Jacobs (2017) would respond to our argument by saying that the dynamic changes in the effectiveness of reinforcers described here are not a property of the reinforcers. Instead, the delivered reinforcer is constant within the session. It is the organism that is changed by the delivery of the reinforcer, and therefore, a term for the organism must be added to our analysis.

We argue in return that this use of the term “organism” is so general as to be useless. At present, it says little more than that behavior does not exist without an organism to behave. As a result, it does not add to our understanding of behavior. In contrast, allowing the terms in the three-term contingency to vary in effectiveness is simpler and more parsimonious because it contains fewer terms to achieve the same goal (three terms rather than four). As argued here, it also leads to work that is theoretically fruitful and practically useful. We do not see such an obvious experimental program emerging from Killeen and Jacobs’ (2017) suggestion at least at this time.

Conclusion

We applaud Killeen and Jacobs' (2017) goal to "... enlarge the realm of what we as behaviorists can assay and accomplish." (p. 7). We argue only for a different approach to that goal than the one they have taken. We argue that an experimental analysis of the factors that control the variables in the three-term contingency can generate findings that are pragmatically useful in controlling behavior and theoretically useful in understanding behavior. As you leave this article, ask yourself a simple question. Is the approach provided by Killeen and Jacobs or the approach provided by this article more useful to you in understanding, controlling, and treating behavior? Of course, the disadvantage of the present approach is that it takes years of hard laboratory work to carry out such an experimental analysis. Nevertheless, hard work is a characteristic of science as we understand it.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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