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COMMENTARY

Predicting Reinforcement: Utility of the Motivating Operations Concept

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Behavior analysts have long recognized that the behavioral function of a given stimulus, including whether or not it serves as a reinforcer, is not fixed. An adequate theory of reinforcement, and hence of behavior, must be able to account for variability in stimulus function, and many behavior analysts have attempted to provide such an account. Killeen and Jacobs (2016) summarize several of those attempts and conclude that none of them are satisfactory. They propose that the way forward is to focus attention on the behaving organism, specifically, on its "affordances" and "dispositions," expanding the venerable three-term contingency to include a fourth variable, "O," the organism in question. As they recognize, this inclusion will trouble many behavior analysts, because Skinner emphasized relations between environmental inputs and behavioral outputs, not the state of the behaving organism, in attempting to explain behavior.

We wish that Killeen and Jacobs (2016) had provided more detail as to how one can quantify and meaningfully categorize "affordances" and "dispositions," but their article is nonetheless provocative. It certainly caused us to think critically about the concept of the motivating operation (MO), a topic of historical and recent interest to us (e.g., Laraway, Snycerski, Michael, & Poling, 2003; Lotfizadeh, Edwards, & Poling, 2014) and one that is certainly relevant to the analysis of reinforcement. We share those thoughts in this article.

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Defining MOs

Other articles detail the historical development of the motivating operation (MO) concept, which has its basis in Michael's (e.g., 1982) work on establishing operations (EOs) (Laraway et al., 2003). As Michael emphasized, in everyday terms the behavior of an organism is determined in large part by what it currently wants and by what is currently available to it. MOs influence what an organism currently wants and discriminative stimuli indicate what is currently available to it. More technically, MOs are defined as changes in the environment of an organism that alter the reinforcing effectiveness of a particular stimulus (e.g., water) or class of stimuli (e.g., potable liquids). According to Laraway et al. (2003), they have two defining effects: "They [are changes in the environment that] alter (a) the effectiveness of reinforcers or punishers (the value-altering effect) and (b) the frequency of operant response classes related to those consequences (the behavior-altering effect)" (p. 412).

Effects of MOs

Distinguishing "value-altering" and "behavior-altering" effects is misleading, because the only way that one can determine whether or not a designated change in an organism's external or internal environment is a MO is by examining that organism's subsequent behavior. Previous discussions of MOs pay surprisingly little attention to how their effects can and should be quantified. Assessment is an important issue because there are several tenable measures. Consider, for example, how one might assess the reinforcing effectiveness of presenting a small amount of water and allowing a person to consume it. Potential measures of the effectiveness of water as a reinforcer include choice for water relative to another stimulus, response rate under a given schedule, latency to respond in a discrete-trial paradigm, resistance to perturbation (behavioral momentum), demand for water as quantified by behavioral economists, breaking point under a progressive-ratio schedule, ease of establishing a new operant with water as the sole consequence, and probability of responding in the presence of discriminative stimuli historically present when water was available.

If a defined change in the environment subsequently alters one or more of these dependent variables relative to a control value (usually, the value obtained when that change did not occur) in a manner indicative of a more effective reinforcer (e.g., it increases the breaking point maintained by water or choice for water relative to the alternative), then it would be considered an EO as the term was defined by Laraway et al. (2003). If the change yields evidence of a less effective reinforcer, then it would be construed as an abolishing operation (AO). It is important to point out that, as Killeen and Jacobs (2016) have suggested, "reinforcer effectiveness" does not specify a physical characteristic of an object or event (reinforcer). Instead, it refers to a category of rather diverse relations among antecedent stimuli, responses, and consequences of those responses. Members of that category may not be affected in the same way by a putative MO. For example, cocaine reduces food intake in pigeons, which is consistent with the known anorectic effects of the drug and suggests that it is an AO for food. But the drug also increases progressive-ratio breaking points with food reinforcement, suggesting it is an EO (Jones, LeSage, Sundby, & Poling, 1995). Researchers and

practitioners need to attend carefully to the techniques they use to assess "reinforcer effectiveness," which is of course necessary to define operations as MOs and to quantify their effects. Good assessment techniques yield data that are directly relevant to the applied problem of concern or to the theoretical question of interest.

The so called behavior-altering effect refers to the control of behavior historically predictive of the availability of the reinforcer of interest (i.e., by discriminative stimuli) and, perhaps less obviously, by other stimuli that are similar to those discriminative stimuli. Several studies, reviewed elsewhere (Lotfizadeh, Edwards, Redner, & Poling, 2012), provide clear evidence that altering the level of food or water deprivation to which laboratory animals are exposed alters stimulus control, as evidenced by changes in the shape and level of generalization gradients. This is a significant effect of MOs, but it is important to recognize that, once the reinforcer of interest has been delivered in a given context, the "behavior-altering" and "value-altering" effects of MOs are confounded. It appears to us that little or nothing is gained by attempting to distinguish between them. Placing emphasis on the distinction is one weakness of the MO concept as historically construed.

Types of MOs

A moment's reflection reveals that a substantial variety of environmental manipulations can alter the reinforcing effectiveness of a particular stimulus or class of stimuli. Consider, for example, the kinds of operations that would increase the reinforcing value of water for our hypothetical person relative to a condition where those operations were not arranged. Five such environmental inputs are (1) imposing fluid deprivation for 24 h, (2), having the person exercise vigorously in a warm room, (3) giving the person warfarin (which causes internal bleeding), (4) cutting the person (causing substantial blood loss), and (5) having a physician tell the person "you're dehydrated and need to drink at least 64 ounces of water a day to keep your kidneys functioning well and stay healthy." The first four operations would not require any particular learning history; hence, they would be what Michael (2000, 2007) called unconditioned establishing operations (UEOs). The fifth would require a learning history, such that the person understood English and trusted the speaker; therefore, it would be what he termed a conditioned establishing operation (CEO).

Michael (2000, 2007) distinguished three subtypes of CEOs, which he termed surrogate, reflexive, and transitive. He and others carefully define these subtypes and reviews of studies demonstrating them have appeared (e.g., Langthorne & McGill, 2009; Langthorne, McGill, & O'Reilly, 2007; Laraway, Snycerski, Olson, Becker, & Poling, 2014). We will not cover this ground, save to make two points. The first is that, as noted in several prior articles (Langthorne et al., 2007; Laraway et al., 2014; McGill, 1999; Miguel, 2013; Smith & Iwata, 1997; Sundberg, 2004), focusing on quantifiable environmental events as determinants of reinforcing effectiveness and attempting to categorize these events in a meaningful way is consistent with the principles of a science of behavior and has benefitted the discipline of behavior analysis. The second is that, as we explained in an earlier article (Lotfizadeh et al., 2014), the subtypes of MOs described by Michael do not provide an exhaustive accounting of the various kinds of events that can influence

the effectiveness of reinforcers. This is a second weakness of the MO concept as construed by Michael (e.g., 2007) and by Laraway et al. (2003).

Although it is of clear heuristic value to distinguish motivational, discriminative, and reinforcing effects of stimuli, the same stimulus may simultaneously produce two or more of these effects in a given context, which complicates the analysis of motivation. As an example, consider a thought experiment in which person, H.A., who is home alone, is visited by a current lover, C.L. The lover has historically provided sexual stimulation when appropriately approached, and hence is a discriminative stimulus for such approach behavior. But seeing, and perhaps smelling, and hearing, C.L. may well sexually arouse H.A., and this action is likely to further strengthen the likelihood of romantic approach responses. If those responses are successful, sexual stimulation will follow, and such stimulation may lead to further arousal and increase the reinforcing value of subsequent stimulation, a good example of priming. Such complex, multiple control of behavior is the rule, not the exception, when human behavior is considered, and must be accounted for in a fully adequate analysis of motivation.

MOs and the Behaving Organism

Killeen and Jacobs (2016) contend that objective physiological characteristics of the organism indicative of its current state often provides direct clues about which events will function as effective reinforcers at a given point in time. We agree. Although this fact is not analyzed in discussion of MOs (e.g., Langthorne et al. 2007; Laraway et al., 2003, 2014, McGill, 1999, Michael, 1982, 2000, 2007), they invariably alter reinforcer effectiveness by creating *physiological changes* in an organism that endure and alter the reinforcing effectiveness of relevant stimuli. That's how they work, period. When these physiological changes dissipate, which is often due to the effects of exposure to the reinforcer in question, the effects of the MO end. For example, the physiological mechanisms responsible for fluid intake are well understood; both osmoreceptors and baroreceptors act on the central nervous system to produce fluid-seeking and fluid-consuming behaviors (Bak & Tsaimi, 2016; Stanhewicz & Kenney, 2015). Many, but by no means all, environmental changes that serve as MOs for water, including the first four environmental changes listed previously, appear to act by affecting these receptors; this is *their physiological mechanism of action.*

As Killeen and Jacobs (2016) suggest, it makes perfect sense to group together MOs that have shared mechanisms of action. Behavioral pharmacologists often refer to such mechanisms of action in analyzing drug effects (e.g., Poling & Bryne, 2000), but behavior analysts rarely do so when examining other kinds of independent variables. Perhaps they should consider doing so. Skinner, of course, consistently emphasized the potential importance of physiological variables to a science of behavior. For example, half a century ago he wrote: "When we can observe the momentary [physiological] state of an organism, we shall be able to use it instead of the history responsible for it in predicting behavior. When we can generate or change a state directly, we shall be able to use it to control behavior" (1969, pp. 283). Humankind's knowledge of physiological processes has burgeoned since he wrote those words, and it is worth examining the extent to which physiological status can be used to predict reinforcer effectiveness. Nonetheless, the specific physiological mechanism of action of many MOs—for

example, arranging a period of time with no social contact and thereby increasing the reinforcing effectiveness of human contact for the isolated individual—is unlikely to be disclosed in the foreseeable future. Thinking about the current value of physiology in explaining MOs reminded us of an old article by Poling and Byrne (1996), whose caution bears repeating:

> Those who await the day when physiologists explain behavior will no doubt derive comfort from an old hymn, "Farther Along". It goes something like this: 'Farther along, we'll know more about it; farther along, we'll understand why; cheer up, my brethren, live in the sunshine; we'll understand it, all by and by.' In the meantime—which may last forever—the best strategy is to isolate variables that influence important behavior and manipulate those variables to make life better. To do so is to be a behavior analyst (p. 79).

Emotions and MOs

Exposure to significant environmental events, including many that serve as MOs, frequently produces subjective states and accompanying overt responses commonly labeled as "emotions." Emotions are caused by physiological changes in an organism, which in their turn are often caused by changes in the external environment. Unlike Killeen and Jacobs (2016), who contend that "emotions change the state of the organism," we view emotions as *indications of the current state of the organism*. As Killeen and Jacobs point out, the effectiveness of particular events as reinforcers or punishers can differ considerably depending on the emotional state of the organism. For example, a food-deprived animal that is "frightened" may not respond to produce food when given the opportunity to do so, although it would consistently do so if not "frightened."

It may well be possible to categorize MOs meaningfully in terms of the emotions they engender. For example, regardless of the specific operations involved in doing so, "making someone angry," is likely to make signs of damage to an instigator positively reinforcing, although these signs would not have the same function prior to the operation (i.e., change in the environment) that made the person angry. Many emotional states appear to have physiological and behavioral correlates that provide reliable clues about which events can function as effective reinforcers when those emotions are present. Humans and other animals are highly adept at attending to behavioral characteristics associated with specific emotional states and responding accordingly, but behavior analysts have dedicated very little time to the systematic study of this behavior and how it might enhance our ability to predict the kinds of events that will function as reinforcers.

Killeen and Jacobs (2016) rightly point out that behavior analysts are paying increasing attention to emotions, and we hope that this attention extends to careful analysis of their potential value in predicting reinforcer effectiveness. Interestingly, it appears that strong emotions are often accompanied by changes in the reinforcing effectiveness of a variety of seemingly unrelated stimuli. For example, as noted, food would be a less effective reinforcer for the behavior of a frightened

rat than for the same animal under comparable conditions when it was not frightened. The same relation undoubtedly would hold for the reinforcing effectiveness of water, wheel running, and access to a mate, hence the operation that caused fear would be an AO for four different kinds of reinforcers. The notion that a given MO is relevant only to a single kind of reinforce rarely holds true. Rather, many kinds of reinforcers are often affected, sometimes in counterintuitive ways. For instance, food deprivation obviously serves as an EO for food as a reinforcer, but it also does so for a substantial variety of self-administered drugs (see, e.g., Sedki, Gregory, Luminare, D'Cunha, & Shale, 2015). An adequate explanation of motivation will have to account for such complex outcomes.

Subjective states (and accompanying behaviors) that would not typically be considered as "emotional," can also provide clues regarding the effectiveness of particular reinforcers. One could, for instance, index the probable reinforcing effectiveness of water as a reinforcer by asking a person "How thirsty are you now?" and using a Likert scale (where, for example, 1 is "not thirsty at all and 5 is "as thirsty as I can possibly be") to quantify responses. Despite the potential limitations of self-report measures, such a strategy has obvious practical value for rough-and-ready assessment of reinforcer effectiveness.

In passing, it is worth noting that the amount of time an unconstrained organism spends engaging in whatever consummatory behavior is relevant to the stimulus in question is probably a good, although not especially convenient, index of whether a change in the environment acted as an MO (cf. Klatt & Morris, 2001). A Premackian analysis of reinforcement suggests that operations which increase this time (relative to a control condition) will serve as EOs, whereas those that reduce it will serve as AOs, although sensitive measures of reinforcer effectiveness are likely to be required to detect these effects.

Verbal Behavior and MOs

In discussing "purpose," Killen and Jacobs (2016) emphasize the fundamental importance of human verbal behavior. This importance extends to determining the effectiveness of particular objects or events as reinforcers. Both overt verbal statements, such as telling a person "you're dehydrated and need to drink at least 64 ounces of water a day to keep your kidneys functioning well and to stay healthy," and covert verbal statements, like saying to oneself before leaving for a run "it sure looks like rain," can alter behavior in ways indicative of an MO effect. The former would in all likelihood increase the reinforcing effectiveness of water, the latter of a rain jacket. If that were the case, then the statements, which many behavior analysts would label as "rules," are "contingency-specifying function-altering stimuli," which is the term Schlinger and Blakely (1987; Blakely & Schlinger, 1987) used to describe the nature and effects of verbal rules. Whether such stimuli should be considered as a special category of MOs, where appropriate, or viewed as another type of controlling variable is open to debate.

As we have previously argued, however, a comprehensive account of motivation must explain how verbal behavior modulates the effectiveness of reinforcers. The MO concept in its current form fails to do so and, in fact, largely ignores verbal behavior (Poling, 2001;

Lotfizadeh et al., 2014). Simply adding "stating rules" to the list of MOs subtypes would be an improvement, but not adequate because (a) it is hard to parse an ongoing stream of verbal behavior into meaningful units, hence to know what, exactly, constitutes a "rule," or the specific consequences (reinforcers) that are relevant to that rule; (b) not all contingency-specifying statements alter reinforcer effectiveness; and (c) the necessary and sufficient conditions for people to generate and follow rules are not specified. Similar objections could be applied to attempts to explain changes in reinforcer effectiveness in terms of overt or covert verbal statements indicative of "purpose."

Concluding Comments

"Everything should be made as simple as possible, but not simpler," the aphorism widely attributed to Albert Einstein, is sage advice for anyone attempting to explain motivation from a behavior-analytic, or any other, perspective. The MO concept developed by Michael (e.g., 1982, 2007) and popularized by him and other behavior analysts (e.g., Langthorne et al., 2007; Laraway et al., 2014; McGill, 1999; Miguel, 2013; Smith & Iwata, 1997; Sundberg, 2004) is relatively simple, and that is one of its two major virtues. The second is that it focuses attention on quantifiable environmental changes as primary determinants of the phenomenon of interest (i.e., reinforcer effectiveness), which is consistent with traditional behavior-analytic approaches and suggests strategies for applied interventions, making it of real pragmatic value. Given these characteristics, it is unsurprising that many behavior analysts, including us, consider the MO concept to be a useful one.

Nonetheless, the concept has met with considerable criticism (e.g., Hayes & Fryling, 2014; Whelan & Barnes-Holmes, 2010). Some of the criticism is justified. For reasons introduced earlier, we believe that the MO concept in its current form is oversimplified and does not provide an adequate analysis of motivation, with motivation narrowly defined to include only the reinforcing effectiveness of particular stimuli (or classes of stimuli) across time, settings, and individuals. Considering the physiological, and perhaps emotional, state of the behaving organism as a determinant of reinforcer effectiveness may be useful in extending the scope and value of the MO concept, as Killeen and Jacobs (2016) suggest, and we encourage other behavior analysts to do so, as will we.

Compliance with Ethical Standards

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

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