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ORIGINAL RESEARCH

Coal Is Not Black, Snow Is Not White, Food Is Not a Reinforcer: The Roles of Affordances and Dispositions in the Analysis of Behavior

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Abstract Reinforcers comprise sequences of actions in context. Just as the white of snow and black of coal depend on the interaction of an organism's visual system and the reflectances in its surrounds, reinforcers depend on an organism's motivational state and the affordances—possibilities for perception and action—in its surrounds. Reinforcers are not intrinsic to things but are a relation between what the thing affords, its context, the organism, and his or her history as capitulated in their current state. Reinforcers and other affordances are potentialities rather than intrinsic features. Realizing those potentialities requires motivational operations and stimulus contexts that change the state of the organism—they change its disposition to make the desired response. An expansion of the three-term contingency is suggested in order to help keep us mindful of the importance of behavioral systems, states, emotions, and dispositions in our research programs.

Keywords Affordance · Affordee · Dispositions · Four-term contingency · Emotion · Law of effect · Linear algebra · Motivation · Notation · States

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For

the rays

are not coloured.

In them there is nothing else

than a certain power and disposition

to stir up a sensation of this or that colour

—Isaac Newton, *Optics* (third ed. 1721/1704)

Coal and snow and food have mass and location and motion. Without observers, they have neither taste nor color nor brightness nor smell. To different observers, they have different tastes and colors and brightness and smells. To a snake's infrared sensors, a bee's compound eyes and a human's trichromatic retina, the same objects have—are given—different colors. Different humans see the same object in different colors, as there are numerous color insensitivities and hypersensitivities among them. The same object has different colors to the same human in different lights. An object can look red with no energy in the red wavelength, depending on what colors surround it (Land, 1964, 1977, 1983).

It is the same with reinforcers. *Queso manchego* is just a cheese, but one that we like—to us a bite can serve as a reinforcer—we will work to get it. Others dislike it—they will work to avoid it. Reinforcers, like the secondary qualities of physics, are not intrinsic—they are not aspects of the thing, but rather of the relation between what the thing affords, its context, the observer, and his or her history (Hayes & Fredericks, 1999; Hocutt, 1967). They are about what the observer is motivated to and is able to do with the thing, given his or her state at that time. In turn, the state is determined by the immediate and historic context. The goal of this essay is to urge that we reinsert the observer—the sometimes reinforceable organism—back into the *operant* and amend its "three-term contingency" notation.

Steps Toward a New Notation

Step 1: Satisfaction

Thorndike did not call reinforcers by that name; he called them *satisfiers*. Recognizing that that needed grounding, he went on to define them as "states of affairs … which the animal does nothing to avoid, often doing such things as attain and preserve." Conversely, "By a discomforting or annoying state of affairs is meant one which the animal commonly avoids and abandons." (Thorndike, 1911, p. 244). These are what are called independent operational definitions. After a hard day's labor, eating a big meal is satisfying. We will attain it if we can. After eating a big meal, eating a big meal is discomforting. We will do things to abandon (escape from) or avoid it (Killeen &

Reilly, 2001). If forced upon us, it would be punishing: same meal, same person, different state, and vastly different effects. The three-term contingency by which we denote a discriminated operant must at least be extended to the quadruple O: $S^d - R - S^R$. For a sign to be an S^d, it must be perceived by an interested organism; responses, R, that are possible in one state of the organism are impossible in other states; for a sign to be an S^R, it must afford the opportunity to do something that the organism cares about—it must allow a biologically and currently "important event" (Baum, 2005) when in that state, designated as O for the state of the Organism. Its presence reminds us that it is that state at the particular time of interest that we must take into account in our science. We give examples throughout the rest of this paper on how that might be done. The same S^d, the same R, and the same S^R will not work the same—will not guide and reinforce—if the organism is in a disinterested state (Staddon, 1993). *Interest* was a centrally important state in William James's psychology; Thorndike referred to the states as *attitude*, *set*, and *readiness*: "The chick, according to his age, hunger, vitality, sleepiness and the like, may be in one or another attitude toward the external situation. A sleepier and less hungry chick will, as a rule, be 'set' less toward escape-movements when confined…" (Thorndike, 1913, p. 13). Without representation of the state variable O, the three-term contingency is equivocal; it does not contain within it an element that represents when it is operative, which stimuli the organism is likely to attend to, and which reinforcers will reinforce. It cannot be a general characterization without that qualifier.

Why not just refer to "a history of reinforcement [and deprivation and…]"? Without a lot more detail than that generic statement, "a history of reinforcement" is an appeal to ignorance. Who can list an adequately complete history of experience preceding any act of interest? And how to make general predictions when each history is particular? "The problem with this view is that it provides no condensation of the data. …It is possible," however, "…to group together histories that are *equivalent*, in the sense that future behavior of the animal…will be the same after any history in the set…The usual way to describe this equivalence is to say that the two animals are in the same *state* after these two *equivalent histories*" (Staddon, 1998, pp. 225–226). There are numerous histories that will generate a particular readiness to drink. We may identify these as yielding the same particular O. The symbol is a marker for a physiological/dispositional/motivational state that we may create with our experimental protocols and that carries the effects of those histories into the present. It is physiological because physiology is the necessary link between stimuli and responses and between past and present; it is dispositional because it increases or decreases the probability that the animal will engage in a class of responses; it is motivational when those dispositions are associated with the efficacy of reinforcers. The past cannot affect the present; it can only have changed environments and organisms that are now present, and such a changed organism is what this symbol marks (Hayes, 1992). Just as the operant response, *R*, is selected from a class of equivalent responses, O is likewise a member of a class. A moment's reflection will show that to be also true for the other terms of the quadruple.

Step 2: What Satisfies

But the above is still not quite right. Premack showed how he could make the same response a reinforcer or a punisher by different motivational operations that deprived or

satiated the organism on that response (e.g., Hundt & Premack, 1963; Premack, 1969, 1971; see Timberlake & Wozny, 1979, for its refinement; Klatt & Morris, 2001, for its evaluation; and Killeen, 2014, for an appreciation). One need not to be an applied behavior analyst to know that toys—things that afford play, not consumption—are effective reinforcers (see, e.g., Fahmie, Iwata, & Jann, 2015). Few natural reinforcers are effective without action by the organism and that action itself, we argue, is the central reinforcing consequence. This is the case for both operant and respondent paradigms (Donahoe, 2014; Killeen, 2014). Such consequential actions can often take on a life of their own (Neuringer, 1970; Osborne, 1977). What, after all, is the stimulus that reinforces the substantial behavioral cost of a child's play? The financial cost of adult play such as sports? Conversely, what is the satisfaction in good cheese that cannot be eaten? Oftentimes, a better term for what we do when a response is getting reinforced is not *consumption*, but *consummation*. Therefore, a step toward the proper notation for the behavioral unit, the quadruple, should be something like: O: $S^d - R - R^C$, with the superscript C indicating a consummatory (or contingent) response.

Step 3: Satisfying Typography

Superscripts are often used to indicate the raising of variables to a power or as an identifier when the subscript place is already occupied by an index. For a more uniform nomenclature we suggest, as a final notation for the operant, this quadruple:

$$O : S_D – R_I – R_C$$

The first term represents the organism after one of a set of equivalent histories leaving it in a corresponding physiological state. It comes first because it affects the efficacy of all other terms of the remaining triplet. The second term stands for a stimulus, which, either initially or after some conditioning, becomes discriminative: Some responses are more likely in its presence than its absence.[1] It is an aspect of the environment in which a particular consequential response, R_C, is more likely to be emitted: $p(R_C|S_D) > p(R_C)$. For that to happen though, the organism must be in a state, O, such that R_C will be a *satisfier* (Thorndike)—an *important event* (Baum). When that is the case, if an additional contingency is imposed, the organism will make R_I—an instrumental response—to approach and begin that consummation; the organism is literally moved—motivated—in that context. Absent the response requirement, we are left with Pavlovian pairing: O: $S_D - R_C$. Pavlovians study responses that are disposed by O: $S_D - R_C$. Skinnerians arrange proximity between one of those responses (making it an R_I) and R_C and study how the occurrence of R_I varies as a function of the parameters of that proximity (Killeen & Pellón, 2013; Pellón & Killeen, 2015). The beginnings of a more formal development of the quadruple are presented in the Appendix.

[1] Because aspects of the environment need to be perceived to function as stimuli, this term might more accurately be represented as R_D. But this may be too deviant a representation for this already taxed audience.

Step 4: Satisfying the Reader

Some readers may ask "What have we left as distinguishing our approach as Behaviorism if we don't take a firm stand against internal states? How do we define ourselves if not by our anti-mentalism?" We remain behaviorists because behavior, its antecedents and consequents, remains our primary concern. We continue to repudiate explanatory just-so stories, including ascription of causation to unmeasured internal states and processes, or to unvalidated histories of reinforcement. Others may ask "Why all the fuss? We are doing just fine with the empirical descriptive behaviorism that we have cut our teeth on. Skinner's aversion to positing inner states was an appropriate reaction against the fulsome assumption of them by Hull and Tolman. It ain't broke; let's not fix it." No, it's not broke. But these authors believe that it is starting to run on empty. Many of the simplifications Skinner wrought in his early work he rescinded in his latter work. He took feelings and dispositions seriously, even while denying their legitimacy. It is our hope that by putting them on the table for discussion and adoption into our system in an explicit and scientifically appropriate way, we may enlarge the realm of what we as behaviorist can assay and accomplish. Please join the conversation.

Reinforcement and the Inner Story

Strengthening

Thorndike employed the concept *reinforce*, or strengthen, in an early version of the matching law: "The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond" (Thorndike, 1911, p. 244). By *bond* he meant the neural connection that made the emission of that response in that situation likely. Whereas the satisfiers "cannot be determined with precision except by observation," he went on, and he noted typical pairs of states and their satisfiers: "Food when hungry, society when lonely …," and related them to drives that improved the life of the individual and species, while also noting the exceptions (e.g., drug abuse).

The original law of effect thus encompassed operationally defined reinforcers and state variables (Staddon, 1993) such as wrought by a history of reinforcement, punishment and deprivation; drives, and emotions; and it attributed changes in probability to changes in underlying neurology. These constituted key parts of Thorndike's early version of Hebb's law: The strengthening or weakening of the bond involved changing "the intimacy [connectivity] of its neurons" at their synapses (Thorndike, 1911, p. 248). Approach to consummatory responses played a key role in determining what constituted a satisfier (R_C) for an animal in that state (O) and thus validated the presence and potency of the particular O: R_C pair.

Skinner streamlined Thorndike's law of effect. "Thorndike's adjectives 'satisfying' and 'annoying' refer to feelings which, in my point of view, is quite off the track" (cited in Bjork, 1997, p. 99). Skinner dropped those terms, and with them, the need for their independent operational definition, rebadging satisfiers for what they did: reinforce, strengthen, or change the probability of responses in other ways. He then switched the

object of that key verb. For Thorndike, it was the neural connection that was strengthened; for Skinner, it was the behavior itself. But what does it mean to strengthen behavior? Not to increase the magnitude of the response, as one might infer from the name, but rather to increase its probability of recurrence in that situation. Skinner's simplified law of effect almost shut the door to the study of the dispositions (systematic changes in the probability of a class of responses) that we call emotions, motivations, and drives (Dougher & Hackbert, 2000; Lewon & Hayes, 2014; only "almost," because he later allowed that "We also control the *dispositions*…" Skinner, 1953, p. 253). Indeed, one can find much that was excised from Thorndike's law recurring throughout Skinner's oeuvre; for example:

> We report an early stage of behaving when we say
>
> "I feel like going for a walk." That may mean "I feel as
>
> I have felt in the past when I have set out for a walk."
>
> What is felt may also include something of the present
>
> occasion, as if to say "Under these conditions I often go
>
> for a walk," or it may include some state of deprivation
>
> or aversive stimulation, as if to say "I need a breath of
>
> fresh air." (Skinner, 1989, p. 13).

Others have called such "early stages of behaving" *interests*, *attitudes*, and *sets*. Skinner recognized that "Behaviorism presupposes inner states, and is inconceivable without them" (Schnaitter, 1987, p. 64): "an animal behaves as it does because of its current structure…what is felt or introspectively observed are certain collateral products of [genetic and environmental] histories" (Skinner, 1974, pp. 18–19). We can parse what he meant by *collateral*. Was it *accompanying as secondary*, or *serving to support or reinforce*? He clearly said that its current structure was causal; yet he consistently argued that it was better to study the external historical causes of those dispositions, rather than to attempt to measure them directly (Jacobs, Isenhower, & Hayes, 2016).

The elimination of state variables representing the animal's "current structure" forces equivocation in the description of behavior. If it is behavior that is strengthened, it should be either strong or weak or somewhere in between. But if the animal is satiated, does erstwhile strong behavior become weak? Then how can it appear strong the next day? If it is weakened through extinction, it is weak. But then how can its strength resurge? Simple neural circuits accomplish these things by requiring serial or parallel operation of modules contingent on states (Donahoe & Palmer, 1994; Donahoe, Palmer, & Burgos, 1997; Koganezawa, Kimura & Yamamoto, 2016), but it is not clear how a lever-press can. Skinner's law of effect was a conditional one: *Given* an effective reinforcer, *here* is what you can do with it. There was enough in it for him and a generation of his students to study to yield many brilliant careers. Now those low-hanging fruits have been plucked.

The Inner Story

Some private events and states are allowed in radical behavior discourse, while others not. Those that are allowed are called *behaviors* (Catania 2013; Hayes & Brownstein, 1986). Purpose and emotion and disposition are typically (but not universally) disallowed.

Purpose A person who feels like going for a walk will typically plan for it. "Sandals or good walking shoes? Will I be back in time? Do I need an umbrella? Should I invite company, or should I stream Pandora?" Planning is often verbally mediated—*rule governed*—and thus engages the great second part of Skinner's theoretical work, his analysis of verbal behavior. Although Skinner dismissed *purpose* as an acceptable explanatory construct, he did allow selection by consequences. One of the "behavioral cusps" (Rosales-Ruiz & Baer, 1997) in our evolution was the ability to use language to plan—to achieve those consequences more effectively. The consequences selected the verbal behavior called *planning*.

An important part of planning is goal setting (Ajzen, 1991). What is the purpose of the walk? Is my goal for the walk serious exercise, or just getting out of the house to check the sunset? Careful goal setting is fundamentally important to effective behavior, and behaviorists have begun to give it some of the attention that it is due, beyond the literature on self-control (see, e.g., Foxall, 2004; O'Hora & Maglieri, 2006; and the excellent overview by Ramnerö & Törneke 2015). Having a purpose is a disposition, making some stimuli, responses, and reinforcers more powerful in controlling behavior than others; it changes O (Gollwitzer, 1993). This is often rule governed: Verbally derived or refined purposes modify motivational states, changing dispositions. Sometimes "we control the dispositions" by talking to ourselves. If the resulting behavior would not have happened, or happened differently, without such talk, we can say that such covert responses mediate that behavior.

Feeling The first wave of behavior analysis and behavior therapy brought "a certain narrowing of vision…. The rejected analytic and humanistic concepts were clinically rich. They generally were designed to address fundamental human issues, such as what people want out of life or why it is hard to be human" (Hayes, 2004, p. 641). The term *love*, considered by many to be an important emotion, appears nowhere in the publication history of two of our major journals (Thompson, 2014). As a self-descriptive tact, it and other such feelings have, however, been given titled place in another one of our journals (McSweeney, 2015; Sulzer-Azaroff, 2015; Taylor, 2015) and substantive presence in another (Kanter, Holman, & Wilson, 2014). In 1935, the behaviorist Thorndike wrote the book on the psychology of wants, interests, and attitudes. We need not commit the mortal sin of dualism to carry forward analyses of these important states (Burgos, 2016; Killeen, 2004) nor need we impute initiating inner causes (Baum, 2011; Killeen, 1984; Hayes & Brownstein, 1985; Zuriff, 1979).

Think about it; if you do, those thoughts may play a causal role in your subsequent behavior, even allowing that they were prompted by our mand. "Think about it" is the same text in all copies of this article, and yet the thoughts and the actions that they prompt will be unique to each reader. How do we understand, predict, or control your resulting thoughts, feelings, and actions? In theory, we could investigate your history of reinforcement before you saw those words. In reality, however, it would be difficult or

impossible, and in that case, it is somewhat unscientific to use it as a "historical cause" when it is a mere allusion. But there are other ways: "The testimony that people give us about their intentions, plans, hopes, worries, thoughts and feelings is by far the most important source of information we have about them" (Foxall, 2004, p. 112; cited in Ramnerö & Törneke, 2015). As all behaviorists know, such reports are fallible; nonetheless, they may provide more immediate and useful information than a seldom-available and also fallible history of reinforcement.

"The failure of behavioral psychology to deal with mentalistic concepts such as beliefs … and pains… has by and large left treatment … to cognitive and physiological psychology. A comprehensive behavioral analysis of such concepts does not currently exist, but such analyses are possible and may be highly useful" (Rachlin, 1998, p. 208; 2014). Eighty years without *wants*, *interests*, *attitudes*, or *beliefs*, and with little or no *love*, had been 80 too long for a science of behavior. Fortunately, times have changed. There is a large and growing behavioral literature on emotions, their conditioning, and transfer (e.g., Augustson & Dougher, 1997; Dymond & Roche, 2009; Boyle, Roche, Dymond, & Hermans, 2016; Dymond, Schlund, Roche, & Whelan, 2014). Do emotions "cause" behavior? They tune the organism, making some stimuli, responses, and reinforcers more powerful in controlling behavior than others (Hayes, Wilson, Gifford, Follette, & Strosahl, 1996; Nomoto & Lima, 2015; Vlaeyen & Linton, 2000). In the language of structural equation modeling, they are moderator variables (Musairah, 2016). Emotions have their own causes, which we may seek, as urged by Hayes and Brownstein (1986). There is no guarantee, however, that we shall find them nor need we necessarily find them to infer and minister to the emotions directly. Emotions change the state of the organism, O. They are an embodiment of dispositions.

Dispositions

Given a reinforcer, there is much that we can do with it. Its power to mold behavior is as unquestionable now (Freedman, 2012) as it was to Thorndike 100 years earlier. No one has realized that power more effectively than Skinner and his students. The important question for our generation is: How do we get "given a reinforcer"? How do we enrich our science so that we do not *start* with the premise that, say, the opportunity to listen to Adele or Drake or Shostakovich will reinforce mp3 purchase; so that we don't treat motivation as an "externality"—a situation that is not part of our science but that we take for granted? Contingencies are conditionals—for example, that the probability of a response will increase given (|) that it is followed by a reinforcer, which is notated as: $p(R_I|R_C) > p(R_I)$. But what gives R_C that power on what occasions has yet to be adequately addressed in our science of behavior. If contingencies are the *raison d'être* of behavior analysis (Lattal, 1995; cf. Timberlake, 2004), then learning how we motivate those contingencies to *do* something has to become a regular and formalized part of our enquiry, as it has for other analyses (e.g., Goldstein, Martin, & Cialdini, 2008; Thorndike, 1935). Behavior analysts have diverse approaches to the topic, as we thumbnail below. What all have in common is a recognition that historical

events may tune the operant, changing the organism's sensitivities to the events in its current environment and rearranging the probabilities of different classes of responses; it is a tune that is orchestrated by O, the state of the organism.

Behavioral Approaches to Disposition/Motivation

Projecting Dispositions and Motivations into the Environment In a defense of Skinner, Place (1987) wondered at Skinner's peripheralization of dispositions. For stimuli: It was not that a punished animal came to fear the whip; the whip itself became aversive. For responses: It is not that we are disposed to smile and wave at friends, but rather that the probability of that response is high. For the response class: It is not about the set of equivalent responses that we are prepared or learn to make in the future as part of an equivalent history; it is a somewhat more platonic realm of potential. For reinforcers: The law of effect is made historical; it explains past behavior, but without a disposition to repeat the reinforced responses in the future, it has no vector to carry it forward. All this was to avoid imputing agency to a disposition. But animals are agents, and what they aspire to and what they achieve are because of their nature, created and modified by their genetic and historical endowment. That nature differs for different individuals, giving some the disposition to whip, others to wave. Both may be shaped. Dispositions, Os, are what we as behaviorists create and study.

Selection by Consequences Skinner's (1985) later conceptualization of reinforcers (and cultures and reproductive success) as agents that select characteristics of ensuing generations provided a framework that spanned genetic, behavioral, and cultural levels of analysis. "Selection by consequences is a causal mode found only in living things, or in machines made by living things" (p. 501); that is, it is Aristotle's *final cause* (Rachlin, 1992, 1998; Killeen, 2001). This was a heroic unification of mechanism across levels. Selection by consequences is different than the concept of strengthening a response (see, e.g., Staddon & Simmelhag, 1971 for a critique of that), because it does not increase or strengthen, but rather selects from among pre-existing variants. There are implications to this analysis. Consequences have not happened, so we must fall back on a history of consequences and that must be embodied in an organism in a particular state in the present. Which consequences matter at a particular point in time depends on the state of the organism. There is no apparent mechanism for selectees by reinforcement that is functionally equivalent to a gene pool in the case of natural selection (Timberlake, 1984). We have the word *repertoire*, a pool from which variants may be selected but have done little work to develop our understanding of it (though Balsam and students have; see, for instance, Balsam & Silver, 1994; Balsam, Deich, Ohyama, & Stokes, 1998).

Which particular set of operants—which repertoires—are available for selection by consequence depends on the state of the organism, O. That state determines which variants are induced, from which selection may occur (Baum & Davison, 2014; Killeen & Pellón, 2013; Segal, 1972). We are back to states again. Although Skinner's unification was a brilliant gambit, it left unaddressed the factors that concern us here: the organization, empowerment, and selectability of candidate responses.

Induction Stimuli, it has been argued, do not by themselves strengthen or select behavior (Baum & Davison, 2014). For Baum (2012), eating is a phylogenetically important event (PIE) that, when constrained by a schedule, results in the induction of PIE-related activities. Appeals to reinforcement strengthening are eschewed, their places taken by constraints on PIEs that induce and control the allocation of time and effort involving PIE-related activities. What puts the I in the PIE? The state of the organism in that context, O (a phylogenetically important motivation (PIM)?). It is *that* that powers the induction.

Response Deprivation Premack and Timberlake and Allison (1974) did not view the presentation of food following behavior to be a reinforcer, but rather the *action of eating* in a particular context to be reinforcing. For Premack, eating reinforces other responses when eating is more probable than those other responses. Measurement of the absolute levels of the probability of a response, however, is problematic (see Premack's enlightening struggle for a solution to the problem of units in Premack, 1959). Eisenberger, Karpman, and Trattner (1967) simplified the measurement by focusing on *changes* in probability. Timberlake and Allison observed that one could make eating, or any other response, more probable by depressing it below its normal *Base* rate, R_{Base}. Operations (whether by an experimenter or by nature) that changed the probabilities of two response classes (R_I and R_C) from baseline in the following way constituted the establishing operations for reinforcement in the experimental context (Exp):

$$\frac{p\left(R_{C,\ Exp}\right)}{p\left(R_{C,\ Base}\right)} < \frac{p\left(R_{I,\ Exp}\right)}{p\left(R_{I,\ Base}\right)} \tag{1}$$

If the probability of R_C decreases from baseline more than the probability of R_I does, then R_C will be able to reinforce R_I. The cause of this inequality—the deprivation of the opportunity to make R_C—is a motivating operation (Michael, 2000). Such deprivation establishes a particular O.

The Motivating Operation A motivating operation is a way of getting an operant going. Motivating operations (MOs) are manipulations that affect O and thereby may change the value of all other terms in the quadruple. Some of the first words on them were, "We induce emotional changes in ourselves for purposes of control" (Skinner, 1953, p. 235). The latest word on them, and their value to behavior analysis, can be found in Laraway, Snycerski, Olson, Becker, and Poling (2014). MOs are the key things that we as experimenters can do to "get given" a reinforcer. But the particular O that it engineers may also arise by factors that we did not arrange (Hineline & Groeling, 2011). It is the O that tunes the operant, whether or not we are the ones responsible for instantiating it; that particular O may exist due to other agencies, or simply the passage of time. The concept of MO is powerful but incomplete unless we accept the name of the thing that it engineers; and that is a motivation, O, the state of the organism that

empowers one or another operant: "according to his age, hunger, vitality, sleepiness and the like, [the subject] may be in one or another attitude [O] toward the external situation." Operations that affect behavioral momentum are MOs, as they change animals' disposition to continue making the R_I in the contexts of distractors. This is equally true of the affiliated concept of arousal (Nevin, 1992, 2003). Cialdini (2016) recounts many instances in which small MOs have substantial effects on significant human behavior, and provides a framework for understanding their mechanisms.

Radical Monism Radical monism (Hayes & Fryling, 2014) rejects most of the above verbal behavior. It (these authors) points out correctly that an MO cannot affect the value of an R_C that has yet to occur. The past is history and has no agency now, and the future does not exist. All that is real is the moment. And indeed, we now know that MOs are often ineffective in changing the reinforcing value of an R_C. This can happen when a response is overlearned and becomes habitual (Dezfouli, Lingawi, & Balleine, 2014)—*automated* in William James's term. Hayes and Fryling are more sympathetic to the evocative function of MOs—induction of response classes in the context of an S_D that is pertinent to a consequence R_C resonating with the organism's state, O. Both classic (Berridge, Robinson, & Aldridge, 2009) and recent (Peterson, Lerman, & Nissen, 2016) research supports this view. In later threads of the strand of behavior, presentation of the reinforcer itself becomes a very important part of the context (e.g., Bouton & Trask, 2016). Setting factors—Kantor's term for MOs—"operate as constituents of the present event. They have no role in events in which they are not present" (Hayes & Fryling, p. 344). Motivational variables "do not determine psychological events, but rather constitute them" (p. 346).

This position has similarities to Rachlin's molar behaviorism (e.g., 1998) in its emphasis on the extended event. It has, we believe, a similar problem of parsimony and generality. Each of us has our own strands of unique moments, extending into what observers would call the past, and pointing, however uncertainly, each to its unique future. But to make statements of some generality, we must find similarities. Our argument follows Staddon's (2016, pp. 75 ff): By rebinding such strands into sheaves with equivalent histories, we become able to more parsimoniously describe their present status and more powerfully predict their future course. The names for those sheaves are particular values for O. That state need not be thought of as an internal cause, but rather as the name of a gathering of similars. To say that it is a disposition is to say that other trajectories in the sheaf tend to behave (in the past have behaved) in a particular way. The brain and body of the organism have been affected by one of those histories, and the organism, embodying that history, carries it forward to affect the current moment. Burgos (2016) provides a thoughtful analysis of such mind-behavior identity theories; our present position falls within that schema: It is a materialist, monist, mind-behavior identity theory, one that includes physiological processes that underlie O—changes in levels of serotonin, oxytocin, adrenaline, activity of astrocytes, etc.—as an important part of its account.

Affordances Embedded within their ecological niches, organisms interact with differentially angled and textured surfaces, differentially rigid and transformative substances, and media through which sound reverberates, light illuminates, and odors diffuse (Richardson, Shockley, Riley, Fajen, & Turvey, 2008). Gibson (1979) called the

differing combinations of these surfaces, substances, and media *affordances*, defined as possibilities for action. Affordances are constrained by an organism's state (O) and what it is capable of doing (Cabrera, Sanabria, Jiménez, & Covarrubias, 2013; Norman, 1988, 1999; Rietveld & Kiverstein, 2014; Timberlake, 1994; Warren, 2006). Animals extend their phenotypes by reengineering the affordances in their environment (Dawkins, 1999).

Affordance is an organizing principle that makes sense of some of the seemingly disparate empirical facts ranging from respondent to operant conditioning, from appetitive to avoidant conditioning. Bolles (1970), for instance, showed that a lever afforded very weak support for avoidance responding; a two-way shuttle better; and one-way shuttles and jump-out boxes afforded conditioning in a few trials under conditions that would have taken hundreds of trials with lever-press avoidance. Not all R_I can be equally well embedded in one quadruple even though they work fine in another: they are not always transsituationally valid, for their affordance is conditional on the O that is operative at that time. There is a historic literature on this fact called *constraints on conditioning* (e.g., Domjan & Galef, 1983).

The nature of a conditioned stimulus (CS)—its affordances for action—affects the form of the conditioned response (CR): A light CS will cause a rat to rear whereas a tone will cause it to jerk its head (Holland, 1977, 1992). Timberlake and Grant (1975) dispensed a rat as a CS prior to food. The CS-rat did not elicit food-related behavior, but rather social affiliative responses. Echoing Thorndike and Timberlake, Domjan (2016) refers to this aspect of control as stimulus *belongingness* [in the quadruple]. He argues that key pecking and lever pressing are neither elicited nor emitted per se, as they are manifest in both classical and operant conditioning (Domjan, 2016). Both procedures, classical and operant, set the O that increases the probability of those classes of behavior, and with the appropriate environmental affordances, the responses will occur. *Elicitation* is used to speak of contexts in which the responses occur with short latency and high probability; *emission* is used to speak of contexts that occasion longer latency or lower probability responses. They are directions on a continuum of affordance, not qualitatively different types.

Environments may afford conflicting actions; then the responses themselves will compete, possibly waxing and waning as a function of time (Pellón & Killeen, 2015). Breland and Breland (1961) called the intrusion of responses that were part of a natural foraging response "instinctual drift." Those responses were more readily induced by the current O and local affordances, and more easily connected within the reinforcement process, than the instrumental responses (R_I) arranged by the experimenters. Boakes's and Timberlake's rats, for example, would hold onto and mouth a ball bearing CSs until food was presented (Boakes, Poli, Lockwood, & Goodall, 1978; Timberlake, 1993). *Affordance* is the current on which responses drift toward modal action patterns. It is ineluctably entwined with the evolution of learning and of new life forms (Ginsburg & Jablonka, 2010; Oyama, Griffiths, & Gray, 2001). What functions as an affordance in one situation and not in another is determined by the O that is operative.

Independently Defined Initial States Functional analyses—the "seat-of-the-pants" technique of cataloging reinforcers or successful contingencies after-the-fact (Timberlake & Farmer-Dougan, 1991, p. 379)—are a way of life in behavior analysis (Timberlake, 2004), one of the jewels in the crown of applied behavior analyses

(Schlinger & Normand, 2013). Still, knowing what contingency works in a particular context does not entail knowing what contingency works in general. Reinforcers are not as transsituationally valid (Meehl, 1950) as one might hope, with the possible exception of generalized reinforcers such as money. Failure to generalize outside the training context is some of the tarnish on the crown of behavior analyses. Knowing why a contingency works (see, for example, Konarski, Johnson, Crowell, & Whitman, 1981) helps deconditionalize it (makes it not depend on whether the operant is currently functional but gives that assurance). Deconditionalizing contingencies entails a specification of initial conditions or state of the organism, O: What the organism brings to the table after eons and hours of contact with selective processes (Timberlake, 1993). These shape many candidate aspects of the organism that can constitute initial conditions down to historical events: The hunger of the mother affects the motivation of the granddaughter; the appetite of the granddaughter affects the tastes of the man. They are measureable (see, e.g., Swails, Zettle, Burdsal, & Snyder, 2016). Once known, contingencies can be arranged around initial conditions and formalized as rules of operation (e.g., with the Premack and other principles, such as regulatory focus and fit: Higgins, 1997).

Behavioral Systems Os are what Timberlake (2001) identified as motivational modes and Higgins, 1997, as regulatory focus; they are reliably observed in coordinated changes in dispositions when evolutionarily relevant stimulus situations activate particular behavioral systems. General search, focal search, and consummatory/handling modes are names for particular motivational modes or states (Os). Such modes reflect the motivation relevant to a behavioral system (e.g., the feeding system), given certain stimulus situations S_D. Motivational modes shift when the CS-US interval is long (general search) or short (focal search), when the CS and US are spatially distal (general search) or proximate (focal search), and if there is a low correlation between a CS and a reinforcement (general search) or high correlation between a CS and reinforcement (focal search; Timberlake, 2001). "The sight of the prey makes the animal run after it, and also puts the conductions and connections involved in jumping upon it when near into a state of excitability or readiness to be made" (Thorndike, 1913). The sight of the prey is an occasion-setter for the behavioral state called predation (Trask, Thraikill and Bouton 2016). Getting motivational modes—phylogenetically important motives—Os—*functioning* is the essence of motivating operations.

Conclusion

The power of Skinnerian behaviorism lies in its simplicity and in its insistence on the primary importance of environmental correlates of behavior. This paper may seem to compromise both strengths. It asks that we take seriously the fact that motivating and conditioning operations do more than change the probabilities of classes of responses; they change the organism, the agent of those responses. Some of the correlates of the states underlying those changes are measurable, whether by galvanic skin response (Mowrer, 1938, demonstrated the power of such measurements in guiding the interpretation of behavior), cortisol, pupillometry, event-related potentials (Ortu & Vaidya, 2016 explore ways to integrate such neural and behavioral data), or questionnaire. Their

measurement may provide a useful complement to histories of reinforcement, when those are available. Invoking states such as joy, love, and satisfaction as part of our understanding of behavior needs not be tautological nor should we fear being labeled mentalists for employing those terms. They are real. Scientifically responsible use of such constructs may help us bridge to other emerging fields.

Embodied cognition (Glenberg, 2010) and affective science (Gross & Barrett, 2013) are two of the newly emerging fields in behavioral science. They are mutually consistent and consistent with our research agendas and philosophical values (Killeen & Glenberg, 2010; and Wilson-Mendenhall, Barrett, & Barsalou, 2013, who observe that "the psychological construction approach to studying situated emotion … invites shifting research agendas from defining five or so emotion categories to studying the rich situations that characterize emotional experiences"). In a review of Barrett (2011), Hackenberg (2014) observed that "Her relational, environment-based, action-oriented perspective is deeply compatible with behavior analysis, and I suspect many behavior analysts will be nodding in agreement with many of the thoughtful and well developed arguments put forth in the book. At the same time, however, the wide-ranging content covered in the book… expands the behavioral perspective in exciting new directions." (p. 131). It is timely for us to consider how we as behaviorist might capture some of the momentum of these fields in our own practice. Expansion of the three-term contingency into the quadruple is a first step in that direction. It is a metaphor that encourages us to reintroduce dispositions into our analyses; a prism to unweave the stream of behavior into the rainbow of its elements, to restore *interest* to our lexicon and *love* to our practice. The decrease in parsimony is a cost that may be more than compensated by the increase in power that it affords.

The light from the sun is "white." After passing through a prism

it shows all the colors which exist in the visible world.

Nature herself reproduces the same result

in the beautiful color scheme

of the rainbow.

———

—Einstein and Infeld, *The evolution of physics* (1938)

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Compliance with Ethical Standards

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

Appendix: Linear Algebra, The Next Step?

Throughout this paper, we have been using the symbol O as a placeholder to represent the state of the organism, the embodiment of a class of equivalent histories, just as S_D represents a class of stimuli, and R_I a class of responses. The argument has been that different emotions, motivations, and purposes act as dispositions, creating affordances out of elements of the environment, making some stimuli more potent, others irrelevant, enabling some response classes, and disabling others. That is a lot for one symbol to do. The four-term contingency is a list of the key elements of the operant, but it could be more. First, write the three-term contingency as a row vector, a list of lists:

$$\mathbf{R} = (\mathbf{S_D}\ \mathbf{R_I}\ \mathbf{R_C}) \tag{2}$$

The boldface indicates that each of the symbols is an array of numbers. We discuss what those numbers might mean below. Write an analogous expression for O; the vector **O** separately represents the coefficients that retune responsivity to stimuli, responses, and reinforcers:

$$\mathbf{O} = (\mathbf{O_D}\ \mathbf{O_I}\ \mathbf{O_C}) \tag{3}$$

Multiply[2] these vectors:

$$\mathbf{B} = \mathbf{O}\circ\mathbf{R}, \tag{4}$$

giving the vector **B** (for behavior) as the quadruple representation of the operant.

Equation 4 can be written out as:

$$\mathbf{B} = (\mathbf{O_D}\mathbf{S_D}\ \mathbf{O_I}\mathbf{R_I}\ \ \mathbf{O_C}\mathbf{R_C}) \tag{5}$$

Now, we have broken out the internal state O as a spectrum of coefficients multiplying the behavioral terms, the behaviors of perceiving, responding, and consuming. These coefficients reflect how relevant each of the components is to the current behavior of the organism. Knowing, say, that an animal is fearful (perhaps it has been shocked or is in an open exposed environment, etc.), then we know that operants involving an R_I of flight or freezing are more easily conditioned than the ones involving exploratory responses (more "prepared" is Seligman's, 1970 term; Fanselow & Lester,

[2] This is called an entrywise or a Hadamard product. In MATLAB, it is known as *array multiplication* and denoted by an asterisk. Throughout, boldface indicates matrices or vectors; lightface labels for things, such as S_D, italics real numbers, such as D_S. *OD* is the strength of a particular stimulus; **OD** a vector of strengths of relevant stimuli. The discussion that follows assumes that **O** and **R** have the same dimensions.

1988) and manipulation more relevant to appetitive conditioning. In aversive conditioning, operants using sounds as S_D will be stronger than those using sights; in appetitive conditioning, sights are better (cf. Bennett, Hermans, Dymond, Vervoort, & Baeyens, 2015). Motivating operations affect O_D as well as O_C (Lotfizadeh, Edwards, Redner, & Poling, 2012). The effectiveness of the consequential response O_C will depend on its duration, among other variables. Some responses induced by the state are so much more fitting to the quadruple (high O_I) that other responses "drift" into their topography. In the process of drift, the affordances of the stimuli in the environment may change to accommodate this dynamic evolution. These readjustments make the operant to a certain extent "self-organizing."

What are the lists in the boldface members of the quadruple operant **B**? How we instantiate them depends on our interests and experimental questions. The components of **R** might stand for all of the possibilities in that environment—the potential stimuli to sense, the instrumental and consummatory responses that can be made. The components of **O** would then weight them by their salience and affordance in that state, selecting out from all possibilities one or a few combinations from **R**. Equations 4 and 5 thus provide a much more general statement than the quadruple in the text, which leaves the components implicit. Establishing numerical values of the components of **O** will be nontrivial, although simplified by contexts with only a few options for each member of **R** and perhaps by using a time-series analysis (e.g., Killeen, Sanabria, & Dolgov, 2009).

In a simple experimental context, the numbers could be the space-time coordinates of each component. Arrangements with high spatio-temporal contiguity of response and reinforcer—that is, where the inner product $\mathbf{R_I} \bullet \mathbf{R_C}$ is large[3]—are the essence of an effective contingency of reinforcement for operant conditioning. An example is when the instrumental response is made close to the source of reinforcement and occurs close in time. Arrangements with high spatio-temporal contiguity of stimulus and reinforcer—that is, where the inner product $\mathbf{S_D} \bullet \mathbf{R_C}$ is large—characterize an effective contingency for respondent conditioning (Donahoe & Vegas, 2004).

The spatio-temporal distances of the instrumental response to the stimulus and to the consummatory response are $D_S = |\mathbf{O_I}\,\mathbf{R_I} \bullet \mathbf{O_D}\mathbf{S_D}|$ and $D_C = |\mathbf{O_I}\,\mathbf{R_I} \bullet \mathbf{O_C}\mathbf{R_C}|$. If the force of attraction to signs and goals is an inverse function of these distances (Killeen, 1992 gives other possibilities), then, depending on the experimental parameters, $\mathbf{R_I}$ will tend to align in space and time either with $\mathbf{S_D}$ (sign-tracking) or with $\mathbf{R_C}$ (goal-tracking). This may be represented as $\mathbf{f} = (\mathbf{O_D}\mathbf{S_D}/D_S + \mathbf{O_C}\mathbf{R_C}/D_C)$, $D_S, D_C > 0$. This is a vector, the resultant of the attraction by $\mathbf{S_D}$ and $\mathbf{R_C}$, which indicates whether the response will aim more at the discriminative stimulus or the goal and how that force will evolve through time. If all are located close together (say, a stimulus is on a key close to a feeder), their directions from a central point are highly positively correlated, conditioning will be optimized (we see this in "stimulus response reinforcer compatibility"). If the animal must move away from the direction of $\mathbf{R_C}$ to make $\mathbf{R_I}$ (the "Umweg Problem"),

[3] The inner or "dot" product of two vectors has different interpretations in algebra and geometry. Here, the geometric interpretation is employed: It gives the consistent magnitude of two vectors—their sum weighted by coincidence of their direction. It is a simple number that ranges from the sum of their magnitudes when they point in the same direction, 0 when they are at right angles, to their signed difference when they point in opposite directions. See https://goo.gl/5p01me.

conditioning will be difficult or impossible. Movement away from $\mathbf{S_D}$ may require much work (negative automaintenance).

The spatio-temporal location of R_C, $\mathbf{R_C}$ may itself be part of two or more operants. Consider situations in which the same space-time coordinates involve both shock and food, which elicit $\mathbf{R_I}$ of opposite sign; this may leave the animal stalled at an intermediate proximity or oscillating in approach and avoidance.

We may compare the similarity of two operants, **B** and **B′** by taking their inner product. The closer the resultant vectors are, the more similar they are. If one wishes to train a discrimination, it would pay to have all terms of **B** and **B′** as different as possible, as seen even with different values for just $\mathbf{R_C}$ (the differential outcomes effect: Estévez, Fuentes, Marí-Beffa, González, & Alvarez, 2001; Urcuioli, 2005). Generalization will increase regularly with the inner product and may be trained for new contexts by varying the elements randomly during conditioning.

In chain schedules, additional elements, corresponding to the componential stimuli and responses must enlarge the representation. This may be represented by the linear combination **B** + **B′**. In this case, the consequences that reinforce the first component will be a signaled delay to the next. Then, the conditioned reinforcing strength, O_C of attaining that stimulus, may be largely determined by a delayed reinforcement model (such as Eq. 10 in Killeen, 2015). Thus, the matrix of the quadruple may serve as the framework for a modular theory of behavior (Gulhardi, Yi, & Church, 2007).

An algebra such as this tracks behavior as it moves through space and time—this is what behavior does; there is no probability, no recurrence, just movement along world lines. To speak of probability, observers and experimentalists frame or impose equivalent histories, as equivalent as they can make them. They control what for their purposes they consider to be spurious causes. Their subjects may or may not respond to these as equivalent histories, but certainly the 20th session in an experimental chamber under baseline conditions is very little different than the 19th. In many cases, the algebra may be used by repositioning the tails of the vectors at the origin after each trial and measuring the resultants in time and space—latency and location—to generate our typical dependent variables.

It should be clear to the reader that nothing in this section constitutes a theory of any kind or even a model; at this point, it is a metaphor, a potential frame. Skinner's good reason for disliking dispositions such as purpose and habit, as well as emotions such as fear and joy, is because it becomes too easy to think that we have explained a behavior of interest by saying something like "That happened because **O** changed; the organism became afraid." Indeed it might have, but the expression does not constitute an explanation until we can measure or arrange that **O**. Many of the papers cited here do just that.

Instead of a theory, we are suggesting that there is an under-utilized opportunity for the three-term contingency and even more for the four-term contingency, the quadruple, to serve as a framework for our evolving theories—possibly in the dialect called linear, or vector, algebra. Such a language provides the opportunity for an intimate working relationship between the inner (**O**) and the outer ($\mathbf{S_D}$ $\mathbf{R_I}$ $\mathbf{R_C}$) stories, as the action of the former on the latter is an operator that converts parts of the environment into affordances. Developments such as this await future behavior analysts, but employment of the quadruple in place of the three-term contingency could become part of our regular practice, as a behavioral commitment to making some such a future happen.

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