Establishing Operations

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The first two books on behavior analysis (Skinner, 1938; Keller & Schoenfeld, 1950) had chapter-length coverage of motivation. The next generation of texts also had chapters on the topic, but by the late 1960s it was no longer being given much treatment in the behavior-analytic literature. The present failure to deal with the topic leaves a gap in our understanding of operant functional relations. A partial solution is to reintroduce the concept of the establishing operation, defined as an environmental event, operation, or stimulus condition that affects an organism by momentarily altering (a) the reinforcing effectiveness of other events and (b) the frequency of occurrence of that part of the organism's repertoire relevant to those events as consequences. Discriminative and motivative variables can be distinguished as follows: The former are related to the differential availability of an effective form of reinforcement given a particular type of behavior; the latter are related to the differential reinforcing effectiveness of environmental events. An important distinction can also be made between unconditioned establishing operations (UEOs), such as food deprivation and painful stimulation, and conditioned establishing operations (CEOs) that depend on the learning history of the organism. One type of CEO is a stimulus that has simply been paired with a UEO and as a result may take on some of the motivative properties of that UEO. The warning stimulus in avoidance procedures is another important type of CEO referred to as reflexive because it establishes its own termination as a form of reinforcement and evokes the behavior that has accomplished such termination. Another CEO is closely related to the concept of conditional conditioned reinforcement and is referred to as a transitive CEO, because it establishes some other stimulus as a form of effective reinforcement and evokes the behavior that has produced that other stimulus. The multiple control of human behavior is very common, and is often quite complex. An understanding of unlearned and learned establishing operations can contribute to our ability to identify and control the various components of such multiple determination.

Key words: establishing operations, motivation, multiple control

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In commonsense psychology, what a person does is generally thought to be a function of two broad factors, knowledge and motivation. For any particular behavior to occur (except for "involuntary" acts such as reflexes), the behaver must *know how* and must also *want* to do it. A good deal of traditional psychological theory concerns the different kinds of wants and the way they interact with other mental functions; much of applied psychology is concerned with getting people to do things that they know how to do but don't want to do. Motivation seems to be an important topic, yet the basic notion plays only a small role in the approach currently referred to as *behavior analysis.*

In applied behavior analysis or behavior modification, the concept of reinforcement seems to have taken over much of the subject matter that was once considered a part of the topic of motivation. To some extent this replacement is reasonable. With the discovery of the role of reinforcement in the *maintenance* of behavior—schedules of intermittent reinforcement—many examples of insufficient motivation could be better interpreted as examples of insufficient ongoing reinforcement. The replacement was also attractive because the more common motivational terms—wants, needs, drives, motives—usually referred to inner entities whose existence and essential features were inferred from the very behavior that they were supposed to explain.

Reinforcement history is not, however, a complete replacement for motivative functional relations. Skinner (1938, chap. 9 and 10, 1953, chap. 9) clearly distinguishes deprivation and satiation from other kinds of environmental variables and relates these operations to the traditional concept of drive, as did Keller and Schoenfeld (1950, chap. 9). Skinner's treatment of aversive stimulation (e.g.,

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1953, chap. 11) is very similar to his treatment of deprivation, and Keller and Schoenfeld classify aversive stimulation as one of the drives (1950, chap. 9). Later, in his treatment of verbal behavior (1957, pp. 28–33, 212–214), Skinner again identifies deprivation and aversive stimulation as independent variables that are quite different in function from reinforcement and stimulus control.[1]

Subsequent behavioral texts at first continued to provide a separate chapter on deprivation (e.g., Holland & Skinner, 1961; Lundin, 1961, 1969; Millenson, 1967; Millenson & Leslie, 1979), but more recent texts have almost dropped the topic (e.g., Catania, 1979, 1984; Fantino & Logan, 1979; Mazur, 1986, 1990; Powers & Osborne, 1976). The handbook by Honig (1966) and the later one by Honig and Staddon (1977) each contain a chapter on motivation by Teitelbaum (1966, 1977); these differ from the earlier treatments in being concerned largely with relations between physiological variables and behavior. The Honig and Staddon handbook also contains a chapter by Collier, Hirsch, and Kanarek (1977), in which feeding behavior is analyzed in the context of its ecological significance. Like that of Teitelbaum, this approach is very different from the earlier ones, and is one that is to some extent critical of some of the assumptions about motivation in Skinner's earlier treatments. Neither the physiological nor the ecological type of analysis seems to have been incorporated in the more recent "nontreatments" of the topic of motivation.

The present state of affairs, with motivative variables being dealt with as reinforcement history, deprivation and satiation, or aversive stimulation, is not entirely satisfactory, however.[2] Variables with behavioral effects similar to those of deprivation and aversive stimulation, but that cannot be easily classified as either, are likely to be ignored or misclassified (usually as discriminative stimuli). What follows is an attempt to provide a more thorough and systematic approach than usually appears, and one that corrects this latter difficulty.

Establishing Operation Defined in Terms of Two Features

An *establishing operation*—the term was first used by Keller and Schoenfeld (1950) and later by Millenson (1967)—is an environmental event, operation, or stimulus condition that affects an organism by momentarily altering (a) the reinforcing effectiveness of other events and (b) the frequency[3] of occurrence of that part of the organism's repertoire relevant to those events as consequences.

The first effect can be called *reinforcer establishing* and the second *evocative.* Thus, food deprivation is an establishing operation (EO) that momentarily increases the effectiveness of food as a form of reinforcement. But food deprivation not only establishes food as an effective form of reinforcement if the organism should encounter food; it also momentarily increases the frequency of the types of behavior that have been previously reinforced with food. In other words, it evokes any behavior that has been followed by food reinforcement. This evocative effect is probably best thought of as (a) the result of a direct effect of the EO on such behavior, (b) an increase in the evocative effectiveness of all S^Ds for behavior that has been followed by food reinforcement, and (c) an increase in the frequency of behavior that has been followed by conditioned reinforcers whose

[1] The topic of emotion is closely related to motivation in these treatments, either as an adjacent chapter (chap. 11 in Skinner, 1938; chap. 10 in Keller & Schoenfeld, 1950; chap. 10 in Skinner, 1953) or as part of a group of closely related independent variables (as in Skinner, 1957).

[2] Kantor's *setting factor* (1959, p. 14) includes motivative variables, but until recently this concept has not been much used within the behavioral community (but see Morris, Higgins, & Bickel, 1982, especially pp. 161 and 167 for a contradictory view).

[3] In this context, *frequency* should be taken to mean both number of responses per unit time and *relative frequency,* the proportion of response opportunities in which a response occurred. This usage makes it possible to avoid such controversial terms as *response strength* and *response probability.*

effectiveness depends on food deprivation. Food satiation—consuming food—is an EO working in the opposite direction; it is actually more accurate to think of motivative variables as establishing or abolishing operations and to think of their evocative effect as an increase or a decrease in the momentary or current frequency[4] of the relevant kind of behavior.

An effort has sometimes been made to interpret the evocative effect of an EO as the result of stimuli produced by the relevant deprivation (hunger pangs, dry mouth and throat) functioning as discriminative stimuli (S^Ds) for the relevant behavior (e.g., Staats, 1963, pp. 111–112). At this point it will be useful to provide a somewhat more restrictive definition of the discriminative relation than usually appears in basic texts and to contrast this relation with that of the establishing operation.

An S^D is a stimulus condition that has a history of correlation with the *differential availability* of an effective form of reinforcement given a particular type of behavior. Differential availability implies that the relevant consequence has been in some way more available in the presence than in the absence of the stimulus condition or S^D. Lowered availability or unavailability in the absence of the stimulus condition further implies that the unavailable event would have been effective as reinforcement if it had been obtained. It is with respect to this latter requirement that most motivative variables fail to qualify as discriminative variables. The ordinary procedure for developing an S^D, as when a rat's lever-pressing behavior is brought under the control of an auditory stimulus in a laboratory setting, consists of allowing reinforcement for lever pressing in the presence of the stimulus, but extinguishing the response in the absence of the stimulus—letting the response occur, but not following it with reinforcement. Although this point is seldom made, the extinction condition always occurs at a time when the unavailable consequence *would be effective* as reinforcement if it were obtained. The unavailability of an ineffective consequence is a behaviorally neutral event. It doesn't constitute an extinction condition, nor does it contribute to a correlation with differential availability. Although it is true that food reinforcement is in a sense unavailable in the absence of the stimuli that we call hunger pangs, this unavailability is not the kind that contributes to a correlation. This issue is also critical for an understanding of the role of painful stimulation as an EO, as discussed later.

To summarize, a useful contrast can usually be made as follows: Discriminative variables are related to the differential *availability* of an effective form of reinforcement given a particular type of behavior; motivative variables are related to the differential *reinforcing effectiveness* of environmental events.

It seems that most events, operations, or stimuli that alter the reinforcing effectiveness of other events also alter the momentary frequency of occurrence of any behavior that has been followed by those other events. Why this should be the case is probably not a question that can be answered by staying within the science of behavior, but can eventually be understood in neurophysiological terms or in terms of evolutionary biology. Although the reinforcer-establishing effect is important for identifying the various EOs and distinguishing them from other types of variables, it is the evocative effect of the EO that is most consistent with commonsense concepts of motivation and with motivational concepts appealed to in other psychological theories. To "want" something can be most easily de-

[4] A change in the momentary or current frequency of *all* behavior that has been followed by a particular type of reinforcement is to be contrasted with a change in the *future* frequency of the particular type of behavior that preceded a particular instance of reinforcement. Changes in future frequency define function-altering relations (reinforcement, punishment, extinction), whereas changes in current frequency define evocative relations (the effects of a discriminative stimulus and the various kinds of establishing operations). For a detailed treatment of this distinction, both for operant and respondent relations, see Michael (1983). In that paper, function-altering effects are referred to as *repertoire altering*.

fined in terms of the momentary frequency of the behavior that has typically obtained whatever is wanted—the evocative EO effect. That the thing wanted will function as more effective reinforcement when and if it is obtained—the reinforcer-establishing EO effect—is not a convenient behavioral interpretation of "want," because it refers to an event that is in the future with respect to the time the "want" is observed.

Unconditioned Establishing Operations (UEOs)

For all organisms there are events, operations, and stimulus conditions whose reinforcer-establishing effects are unlearned. They depend upon the evolutionary history of the species, and vary from species to species. Note that it is the unlearned aspect of the reinforcer-establishing effect that results in an EO being classified as "unconditioned." The behavior evoked by the EO is usually learned. Said another way, we are probably born with the capacity for our behavior to be more reinforceable by food as a result of food deprivation and more reinforceable by pain cessation as a result of pain onset, but we have to learn most of the behavior that produces food and terminates pain and is thus typically evoked by these EOs.

Deprivation and satiation. Some forms of deprivation serve as unconditioned establishing operations (UEOs) for humans and related mammals. Food, water, activity, and sleep are things that these animals can be deprived of with resultant reinforcer-establishing and evocative effects. Food and water consumption, engaging in activity, and sleeping are operations that work in the opposite direction. Salt ingestion, perspiration, and blood loss are operations that have much the same effect on behavior as water deprivation does—water becomes more effective as a form of reinforcement, and behavior that has been reinforced with water becomes momentarily more frequent.

Temperature changes. A decrease in skin temperature or in general body temperature below normal values increases the reinforcing effectiveness of a change in the opposite direction, and more remotely of warm objects, places, and clothing. These changes also increase the momentary frequency of the behavior that has accomplished them. An increase above normal values is an EO that has reinforcer-establishing effects in the opposite direction and evokes the behavior that has resulted in a body-cooling effect. These EOs could also be dealt with under the category of aversive stimulation, which includes painful stimulation, but it may be clearer to consider them separately, especially considering the problems of *aversive stimulus* as an omnibus term, as discussed later.

Variables relevant to sexual reinforcement. For many nonhuman mammals, hormonal changes in the female are triggered by time passage, ambient light conditions, daily average temperature, or other features of the environment related phylogenically to successful reproduction. These environmental features, or the hormonal changes themselves, can be considered UEOs in making sexual contact with the male an effective form of reinforcement for the female, and simultaneously causing the production of chemical (olfactory) attractions that function as EOs for the male. The various hormonal changes may also elicit (or sensitize for easier elicitation by other stimuli) certain behaviors (e.g., the assumption of sexually receptive postures) that then function as UEOs or as respondent unconditioned elicitors (UEs)[5] for sexual behavior by members of the opposite sex. Superimposed on this collection of UEOs

[5] The term *unconditioned stimulus* actually refers to two quite different functions, for which it is convenient to have separate terms. In the Pavlovian arrangement, for example, food elicits salivation when it is placed in the mouth, and it also alters the function of other stimuli present at the same time (e.g., a tone) so that in the future, when those stimuli are presented by themselves, they too elicit salivation. The food can be said to function as an unconditioned elicitor (UE) and as an unconditioned conditioner (UC). For a more detailed treatment of this distinction and related terms see Michael (1983).

and UEs is a deprivation effect that may also function as a UEO.

In the human, the situation is quite complex and not well understood. The behavioral role of hormonal changes in the female is not clear, nor is the role of chemical attractants in changing the male's behavior. There do seem to be deprivation effects for both sexes. In addition, tactile stimulation of erogenous regions of the body seems to function as a UEO in making further similar stimulation even more effective as reinforcement and in evoking the behavior that has in the past achieved such further stimulation. But the possible role of learning in these various relations cannot be ruled out.

Painful stimulation: Escape. The onset of painful stimulation establishes the reduction or offset of this stimulation as an effective form of reinforcement and evokes the behavior that has achieved such reduction or offset. That painful stimulation is a UEO rather than an S^D is not well appreciated. The issue can be most easily analyzed by reference to a typical laboratory shock-escape procedure. The response that turns off the shock (often a lever press) is clearly evoked by the shock onset, and it is also clearly a part of an operant rather than a respondent relation because it was developed through the use of shock offset as reinforcement. If the only known operant evocative relation were the S^D, then shock onset would seem to be an S^D; but, like the stimuli called hunger pangs, it fails to qualify as a discriminative variable because its absence has not been a condition in which an effective form of reinforcement was unavailable for a particular type of behavior.

To repeat the argument, an S^D is a stimulus condition that has been correlated with the *availability* of a type of consequence given a type of behavior. A correlation with availability has two components: An effective consequence (one whose EO was in effect) must have followed the response in the presence of the stimulus, and the response must have occurred without the consequence (which would have been effective as reinforcement if it had been obtained) in the absence of the stimulus. The correlation between painful stimulation and consequence availability fails in the second component. In the absence of shock, there is no effective consequence that could have failed to follow the response in an analogue to the extinction responding that occurs in the absence of an S^D. In the absence of shock, the relevant establishing operation is absent. The fact that the lever press does not turn off the "nonpresent" shock is in no sense extinction responding, but rather is behaviorally neutral, like the unavailability of food reinforcement when one is satiated. Contrast this situation with extinction when an S^D is absent—the food-deprived rat presses the lever but fails to receive food, which would at that moment be effective as reinforcement if it were obtained. The absence of the shock is more like the absence of food deprivation than like the absence of the S^D. With no shock present, shock termination is not an effective form of reinforcement.

Note that in addition to its EO evocative effect, the onset of a painful stimulus also functions as a respondent UE in eliciting a number of smooth muscle and gland responses such as increased heart rate, pupillary dilation, adrenal secretion, and so forth; as a respondent UC (unconditioned conditioner) in conditioning these responses to other stimuli present at the time; as an S^P (it is convenient to use the symbol S^R for unconditioned reinforcement and S^r for conditioned reinforcement; similarly, S^P is used for unconditioned punishment and S^p for conditioned punishment) in decreasing the future frequency of any type of behavior that precedes it; possibly as an S^D for any response that has been correlated with the availability of some form of reinforcement other than pain reduction (e.g., lever pressing for food); and possibly as a respondent CE (conditioned elicitor), if pain has been paired with some other UC (unconditioned conditioner) such as food, in which case pain might elicit salivation (this would probably work only with mild pain because intense pain as a UE would probably elicit autonomic activity that is incompatible with salivation).

It is possible that, in general, there is a close correlation among several of these functions. Maybe any stimulus, the onset of which can function as a UEO in evoking its own termination, will also function as a UE and a UC with respect to certain smooth muscle and gland responses (the activation syndrome, for example), and will also function as an S^P in weakening any response that precedes its onset. This seems to be the implication of much current use of the term *aversive stimulus,* where the specific behavioral function is not identified. It is not clear at present just how close the correlation among these functions is, nor is it clear that the advantages of an omnibus term of this sort outweigh the disadvantage of its lack of specificity. It *is* clear that some use of this term is simply a behavioral translation of commonsense expressions for "feelings," "states of mind," and so on, an undesirable usage that is fostered by the term's lack of specificity. The same problem arises when "reinforcement" is used without the implication of a strengthening effect on preceding behavior, but rather as a synonym for "pleasant" or "desired," as in the too often heard "That's very reinforcing!"

To keep the term *reinforcement* specific to its strengthening function and still have an omnibus term for positive events, one might use *appetitive* as the opposite of *aversive.* In this usage, an appetitive stimulus or condition would be one that elicits certain smooth muscle and gland responses, conditions neutral stimuli so that they elicit similar responses, increases the future frequency of the type of behavior preceding its onset (S^R), suppresses the behavior that removes it (UEO), and decreases the future frequency of the behavior that precedes its termination (S^P). This use of *appetitive* is often presented in basic textbooks, but seems not to be used much in the area of behavior analysis, possibly because it still seems to refer primarily to eating.

Perhaps the omnibus usage is essential for effective behavioral discourse, or perhaps it can be and should be avoided in favor of more specific terms. In any case, proper use of *aversive stimulus* is often problematic, and *appetitive* doesn't seem to be catching on, but this is not the place to do other than identify the difficulty.

Unconditioned reinforcement. Many introductory behavioral treatments identify environmental changes that function as reinforcers in the absence of any particular learning history as unconditioned reinforcers (S^Rs). They are contrasted with conditioned reinforcers (S^rs), whose reinforcing effectiveness depends upon some association with unconditioned reinforcers. Unconditioned establishing operations are the environmental events, operations, or stimulus conditions that regulate the momentary effectiveness of unconditioned reinforcers (and also the momentary effectiveness of the conditioned reinforcers based on those unconditioned reinforcers). The UEO and the S^R are obviously closely related, but it would be a mistake to consider the terms synonymous. Food deprivation is the UEO that regulates the effectiveness of food as an S^R. The above list of UEOs implies a corresponding list of unconditioned reinforcers.

It is possible that there are forms of unconditioned reinforcement that are not related to any particular UEO. For example, infants' behavior seems to be reinforceable by a variety of mild stimulus changes[6] (Finkelstein & Ramey, 1977; Kalnins & Bruner, 1973; McKirdy & Rovee, 1978; Rovee & Fagen, 1976; Watson, 1967; Watson & Ramey, 1972) not easily related to any obvious EO. The concept of *intrinsic motivation,* as proposed by Deci and Ryan (1985, chap. 1 and 2), seems to imply that "signs of competence" and "signs of self-determination" always function as effective forms of unconditioned reinforcement, although they can be temporarily weakened by the presence of other UEOs and other momentarily strong forms of reinforcement. What such signs might con-

[6] I am indebted to Henry Schlinger for reminding me of this point and for directing my attention to the references shown.

sist of for the untrained organism is not clear, and current evidence for such reinforcement is equally well interpreted in terms of Skinner's concept of generalized conditioned reinforcement (1953, pp. 77–81). However, the issue is essentially an empirical one, and either interpretation is compatible with a behavioral approach to motivation.[7]

Painful stimulation: Aggression. In addition to establishing its own reduction as a form of reinforcement and evoking the behavior that has produced such reduction, painful stimulation in the presence of another organism evokes aggressive behavior toward that organism. Skinner, in *Science and Human Behavior* (1953), discussed this effect in attempting to explain the responses that vary together in emotion. He identified two bases for such covariation.

> Responses which vary together in an emotion do so in part because of a common consequence. The responses which grow strong in anger inflict damage upon persons or objects. This process is often biologically useful when an organism competes with other organisms or struggles with the inanimate world. The grouping of responses which define anger thus in part depends upon conditioning. Behavior which inflicts damage is reinforced in anger and is subsequently controlled by the conditions which control anger. (p. 163)

This covariation is based on ontogenic factors or on a history of reinforcement. Phylogenic factors may also be involved.

> Some of the behavior involved in an emotion is apparently unconditioned, however, and in that case the grouping must be explained in terms of evolutionary consequences. For example, in some species biting, striking, and clawing appear to be strengthened during anger before conditioning can have taken place. (pp. 163–164)

About 10 years after *Science and Human Behavior* was published, Ulrich and Azrin (1962) first reported their discovery of the phenomenon that came to be known as elicited aggression: the unlearned occurrence of biting, striking, and so on, as a result of painful stimulation, found to occur in a wide variety of species. It thus appears that one of the effects of painful stimulation is simply to elicit aggressive behavior as an unconditioned response. But the issue is still not entirely clear, because some or all of the effect may be the result of pain as a UEO (rather than as a UE), where pain increases the effectiveness of some form of reinforcement specific to that EO, such as signs of damage to another organism or the feel of one's teeth being pressed against something. The aggressive behavior would thus be an example of what Skinner later referred to as an *intermingling* of phylogenic and ontogenic contingencies (1974, pp. 45–50, where the EO has its reinforcer-establishing effect, which then leads to a form of rapid operant shaping of the appropriate behavior. These various mechanisms need not be mutually exclusive, and there is considerable evidence for multiple provenances for these kinds of behavior.

Other emotional EOs. The above analysis of painful stimulation as an EO with respect to aggressive behavior can probably be extended to the other operations that produce so-called "emotional behavior" or "emotions." In *Science and Human Behavior* (1953), Skinner describes the operant aspect of emotion as a *predisposition,* as follows:

> The "angry" man shows an increased probability of striking, insulting, or otherwise inflicting injury and a lowered probability of aiding, favoring, comforting, or making love. The man 'in love" shows an increased tendency to aid, favor, be with, and caress, and a lowered tendency to injure in any way. "In fear" a man tends to reduce or avoid contact with specific stimuli—as by running away, hiding, covering his eyes and ears; at the same time he is less likely to advance toward such stimuli or into unfamiliar territory. These are useful facts, and something like the layman's mode of classification has a place in a scientific analysis. (p. 162)

Skinner doesn't specifically identify the reinforcer-establishing effect of the EO here, but in the previous passage this implication is quite clear. Of course, as he points out in discussing "the total emotion" (p. 166), one must add the respondent UE and UC effects of emotional operations, and we should also add the possible effects of such operations as unconditioned reinforcement or punish-

[7] For a detailed behavioral analysis of the topic of intrinsic motivation, see Bernstein (1990) and Dickinson (1989).

ment for the behavior that precedes the occurrence of the operation, for a complete picture of the "total emotion" (Skinner, 1953, p. 166).

EOs and punishment. If EOs must be in effect for events to function as reinforcement, it is reasonable to consider their function with respect to punishment. Painful stimulation as punishment *functions as its own EO,* but other forms of punishment, particularly those involving withdrawal or removal of reinforcing events, would be expected to function as punishment (i.e., would decrease the future frequency of the kind of behavior that they followed) only if those events were effective as reinforcement at the time they were withdrawn. It is not punishment to take food away from a food-satiated organism.

The evocative effect is more complex. Suppose removal of food from a food-deprived animal was used as a form of punishment for some particular type of behavior (which was being reinforced in some other way—for example, by access to sexual stimulation). We must assume that the current weakening effect of this history of punishment would be seen only when the organism was food deprived. This relation has not received much theoretical or experimental attention, but seems to follow naturally from existing knowledge of reinforcement, punishment, and establishing operations. (Note that this relation makes the detection of a punishment effect doubly complex: The effect of punishment will not be seen unless the EOs relevant to the reinforcement maintaining the behavior and to the punishment weakening it are both in effect—in the example above, unless sexual stimulation and food are both effective as reinforcement.)

A respondent analogy. As described above, the EO is strictly an operant evocative relation, but there may well be a respondent analogy. Food deprivation probably increases the evocative and function-altering effectiveness of food as a stimulus (that is, as UE and UC) as well as of stimuli that have been correlated with food (as CEs and conditioned conditioners [CCs]). Similar relations may exist for many of the unconditioned reflexes, in which case respondent evocation, like operant evocation, should be conceptualized as jointly controlled by the EO and UE (or CE).[8]

Conditioned Establishing Operations (CEOs)[9]

Ordinary forms of conditioned reinforcement do not require a special EO for their effectiveness; the UEO appropriate to the relevant unconditioned reinforcement is sufficient. In other words, many learned forms of reinforcement do not require learned EOs. Nevertheless, there are variables that alter the reinforcing effectiveness of other events, but only as a result of the individual organism's history. These are learned or conditioned establishing operations (CEOs). As with the UEOs, they also alter the momentary frequency of the type of behavior that has been reinforced (or punished) by those other events. There are at least three kinds of CEOs. They are all stimuli that were motivationally neutral prior to their relation to another EO or to a form of reinforcement or punishment. They differ in terms of the nature of their relation to the behaviorally significant event or condition. The simplest relation is a correlation in time; the neutral event is paired with or systematically precedes a UEO (or another CEO). As a result of this pairing, the neutral event may acquire the motivational characteristics of the UEO that it is paired with. I refer to this as a *surrogate*[10] CEO.

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[8] I am grateful to Michael Commons for pointing out the possible relevance of the EO concept to respondent relations.

[9] In Michael (1982), I suggested the term *establishing stimulus* and the symbol S^E for a learned motivative relation, with *establishing operation* (EO) referring to the unlearned relation. It now seems that *conditioned establishing operation* (CEO) works better because of the easier contrast with *unconditioned establishing operation* (UEO). This approach also leaves *establishing operation* (EO) as a useful term for the general motivative relation, without specifying provenance.

[10] The term *surrogate* was suggested by Michael Urbach.

A more complex relation is one in which a stimulus systematically precedes some form of worsening,[11] and if the stimulus is terminated prior to the occurrence of this worsening, the worsening does not occur. This relation is exemplified by the warning stimulus in an avoidance procedure, and this type of stimulus acquires the capacity to establish its own termination as an effective form of conditioned reinforcement and to evoke any behavior that has accomplished this termination. In the opposite direction, a stimulus that systematically precedes some form of improvement, and whose termination prevents the occurrence of the improvement, will acquire the capacity to establish its own termination as a form of conditioned punishment and to suppress any behavior that has accomplished this termination. In an earlier paper (Michael, 1988) I referred to these as a *threat* CEO and a *promise* CEO. It now seems more reasonable to refer to a CEO that establishes its own termination as a form of reinforcement or punishment as a *reflexive* CEO, a term that is more indicative of the effect of this CEO in altering its own function. (*Reflexive* here is meant in the grammatical sense, not as referring to a reflex. This usage is thus somewhat similar but not identical to the mathematical and logical use that occurs in the context of equivalence relations.)

An even more complex relation exists in the correlation of a stimulus with the correlation between another stimulus and a form of unconditioned reinforcement. The term *conditional conditioned reinforcer* refers to just such a relation. The stimulus upon which the effectiveness of the conditioned reinforcer depends is a CEO, in that it establishes the effectiveness of another event as reinforcement and evokes any behavior that has produced this other event. This type of CEO can be called *transitive*, in contrast to the reflexive CEO. (Again, this is the grammatical usage, as with a transitive verb that takes a direct object.) As with the reflexive CEO, one must consider both the positive and the negative case. With a conditional conditioned punisher, the stimulus upon which the effectiveness of the conditioned punisher depends is a CEO, in that it establishes the effectiveness of another event as punishment and suppresses any behavior that has produced this other event. In an earlier paper (Michael, 1988) I suggested the term *blocked-response* CEO for this relation, because many human examples were characterized by a stimulus change functioning as an S^D for a response that could not take place until some object was available, and thus functioning as a CEO in establishing the object as a conditioned reinforcer and evoking the behavior that had obtained such an object. The slotted screw example (described below) has this pattern, but some CEOs of this type are simply a stimulus upon which the reinforcing effectiveness of another stimulus depends, but with no response blocked (like the nonhuman example of lever pressing). The three CEO types will now be considered in detail.

Surrogate CEO: Correlating a stimulus with a UEO. The development of the CE (conditioned elicitor), S^r (conditioned reinforcer), and S^p (conditioned punisher) each involves pairing or correlating a neutral event with a behaviorally effective one as a way of giving the neutral event some of the behavioral properties of the effective one. It is not unreasonable to suppose that properties of the EO could be developed in the same way. The question is, would a stimulus that had been correlated with a UEO become capable of the same reinforcer-establishing and evocative effects as that UEO? The terms *learned drive* or *acquired drive* appeared

[11] I use the term *worsening* to refer to any stimulus change that *would function* as punishment for the type of behavior that preceded it. I avoid the term *punishment*, because in the context of describing this CEO I am not referring to the decrease in future frequency of any behavior. Similarly, I use *improvement* for a change that *would function* as reinforcement for the type of behavior that preceded it, but I am not referring to an increase in the future frequency of any behavior in this context. The term *aversive stimulus* would be appropriate, except for my general uneasiness about omnibus terms, as expressed earlier. *Worsening* should be considered a term from everyday usage, not a technical term.

quite often in the early learning literature. A chapter by Miller, entitled "Learnable Drives and Rewards," was included in the 1951 Stevens *Handbook of Experimental Psychology*. Much speculation regarding human behavior has taken the form of postulating various learned motives, but as Miller pointed out, "the experimental work on learned drives and rewards is limited almost exclusively to (1) fear as a learnable drive and fear reduction as a reward or (2) learned rewards and drives based on hunger and food" (1951, pp. 435–436). Although couched in the language of hypothesized internal drive states, the work on fear as a learnable drive is primarily concerned with the motivative characteristics of the warning stimulus in an avoidance situation (the reflexive CEO described in detail below). Miller's section on learned rewards and drives based on hunger and food (1951, pp. 454–462) dealt extensively with the development and use of learned rewards (conditioned reinforcers), but considered learned drives only briefly. Subsequent to that publication, there was some research on the possibility of developing a learned appetitive drive in a laboratory situation. The question was whether stimuli correlated with high levels of food deprivation would produce, by themselves, a momentary increase in the frequency of the behavior that had been reinforced by food. Also, would they increase, by themselves, the effectiveness of food, water, and so on, as forms of reinforcement? (Of course these questions could be asked just as reasonably about other UEOs, such as water, sleep, activity, or sex deprivation, but most of the research involved food deprivation.)

In the first experiment of this type, Calvin, Bicknell, and Sperling (1953) placed rats in a distinctively striped box for 30 min a day for 24 days. During this training one group was placed in the box while food deprived for 22 hr, and the other group was placed in the box while deprived for only 1 hr. After training, both groups were allowed to eat in the striped box following 11.5 hr of food deprivation; the rats with the history of 22-hr deprivation ate significantly more than the group with the history of 1 hr of deprivation. There were several attempts to replicate these results during the next several years; some were successful, but most failed to produce similar results. In a comprehensive review of this line of research, Cravens and Renner (1970) identified several major methodological problems with most of the research, and concluded that the results were essentially uninterpretable.

Mineka (1975) suggested that gustatory and olfactory stimuli are more appropriate as conditioned elicitors for a hunger drive than are the visual stimuli that had been used in most of the previous studies. She conducted a series of experiments comparing visual and gustatory stimuli, with favorable results when the latter were used, but then failed to replicate those results in a subsequent experiment, and ultimately concluded that the phenomenon may not exist. Mineka also made an interesting point about the possible biological uselessness of such learned appetitive drives, in that eating more than is appropriate for a given deprivation level simply because one has been hungry in that particular stimulus condition before would not be to the organism's long-term advantage or survival.

Not much research of this type has appeared since Mineka's 1975 report, but it would be premature to exclude the possibility of this CEO on the basis of the unclear empirical evidence or hypothesized negative survival value. Deprivation–satiation UEOs typically build up slowly, and it is not easy for a stimulus to become correlated with the extreme values of such a build-up. UEOs with more rapid onset, however, are often paired with relatively unique stimuli that might be expected to develop CEO properties. Would stimuli that were correlated with decreases in temperature, for example, have CEO effects similar to the effects of those temperature decreases themselves? In the presence of such stimuli, would warmth be more reinforcing than would be appropriate for the actual temperature, and would behavior that has produced such warmth be more frequent than it ought to be for the actual temperature?

Note that this question is not about the possibility of conditioned elicitation or conditioned reinforcement or punishment. It is well known that a neutral stimulus (e.g., a tone) paired with cold (hand dipped in ice water) will come to elicit appropriate smooth muscle responses (peripheral vasoconstriction) when it is presented alone. It is also quite clear that if the onset of the cold stimulus functions as punishment (S^P) for any response that precedes it, then so too will any stimulus that is correlated with such onset (S^p). Neither of these functions (CE, S^p) is synonymous, however, with the operant evocative effect of an EO, although their occurrence might always be a good basis for predicting the CEO effect, which might well be based on the same physiological processes. I know of no research bearing directly on the existence of a CEO evocative effect based on pairing with temperature changes, but the possibility seems worth considering.

With sexual motivation, EOs for aggressive behavior, and the other emotional EOs, the issue has not been addressed in terms specific to the CEO, because its distinction from CE, S^r, and S^p has not been previously emphasized. There is evidence that a stimulus correlated with painful stimulation will increase the frequency of aggressive behavior when presented alone (Farris, Gideon, & Ulrich, 1970), but it is not clear whether it is functioning as CEO, CE, or both. The basic experimental design is simple enough: Correlate a neutral stimulus condition with a UEO, and then see if by itself it increases the reinforcing effectiveness of the consequence relevant to the UEO and increases the momentary frequency of the behavior that has been developed through reinforcement by that consequence. Reinforcing effectiveness is not easy to quantify, but the evocative effect should be easy to measure, and its presence should be evidence enough for the CEO effect. One must, of course, use behavior that is clearly of learned operant origin to prevent confusion of CEO with CE. Thus, with painful stimulation and aggressive behavior, if the potential CEO evokes some arbitrary response (such as lever pressing) that has been developed by reinforcement with access to another organism to attack, then it is functioning as a CEO rather than a CE, because there is no UE for such behavior. The issue would not be clear if the behavior studied was striking, biting, and so forth, because these may be elicited by painful stimulation as a UE. Similarly, with sexual motivation, if the previously neutral stimulus evoked an arbitrary response (such as lever pressing) that had been reinforced with access to sexual stimulation, it is functioning as a CEO rather than a CE, but the issue would be unclear if the behavior was pelvic thrusting, which might have been elicited by a UE.

The possibility of developing a surrogate CEO based on painful stimulation as a UEO for escape behavior must be carefully distinguished from the next type of CEO (to be discussed below). The issue is whether correlating a neutral stimulus with painful stimulation will increase the effectiveness of pain reduction as a form of reinforcement and evoke the behavior that has been reinforced with pain reduction. It is not clear what it means to increase the effectiveness of pain reduction when no pain is present, but such a stimulus in the presence of mild pain might cause the mild pain reduction (along with the reduction of the CEO) to be more like the reduction of more severe pain. Much less difficult to measure would be the extent to which such a stimulus evoked the pain-escape response in the absence of pain. In the typical shock-escape experiment, all that is necessary is to precede the onset of shock with a warning stimulus and see if the shock-escape response is increased in frequency by the onset of the warning stimulus. Note that this is not the typical escape-avoidance procedure. As described below, there is no question that a stimulus that systematically precedes the delivery of a second, painful stimulus will evoke the behavior that terminates the first stimulus and thus avoids the onset of the pain. Here the question is whether the warning stimulus will evoke the response that terminates the *pain,* even though the pain is not yet present, and even though such a response has not prevented the onset of pain.

The situation can be clarified by reference to an unusual type of avoidance experiment, one with escape and avoidance responses of quite different topographies. Imagine a rat in a procedure in which a lever press terminates the shock but a wheel turn terminates the warning stimulus and avoids the shock. The present CEO would be demonstrated if the warning stimulus evoked the lever press; the CEO discussed below would be demonstrated if the warning stimulus evoked the wheel turn. The occurrence of such behavior could have other interpretations, but it will probably be possible to exclude these with appropriate experimental designs. This process, like the ones described above, seems intuitively quite plausible, but research directed precisely at the CEO issue has not yet been conducted.

Reflexive CEO: Correlating a stimulus with worsening or improvement. In the traditional discriminated[12] avoidance procedure, an intertrial interval is followed by the onset of an initially neutral warning stimulus, which is in turn followed by the onset of painful stimulation—usually electric shock. Some arbitrary response (i.e., one that is not part of the animal's phylogenic pain-escape repertoire) terminates the painful stimulation and starts the intertrial interval. The same response, if it occurs during the warning stimulus, terminates that stimulus and starts the intertrial interval, thus avoiding the shock. As a result of exposure to this procedure, many organisms acquire a repertoire that consists of making the relevant response during most of the occurrences of the warning stimulus.

Recall the analysis of the role of shock as an EO for the escape response, the reinforcement for which is shock termination. The warning stimulus has a similar function, except that its capacity to establish its own termination as an effective form of reinforcement is of ontogenic provenance—due to the individual's own history involving the correlation of the presence of the warning stimulus with the onset of the painful stimulation. In other words, the warning stimulus as a CEO evokes the so-called avoidance response, just as the painful stimulation as a UEO evokes the escape response. In neither case is the relevant stimulus correlated with the availability of the response consequence, but rather with its reinforcing effectiveness.

In more general terms, any stimulus that is positively correlated with the onset of painful stimulation becomes a CEO, in that its own offset will function as reinforcement and it will evoke any behavior that has been followed by this reinforcement. But this set of functional relations is not limited to painful stimulation as a form of worsening (or even to worsening, as will be seen later). It is well known that organisms can learn to avoid forms of stimulus change other than the onset of pain. Stimuli that warn of a lowered frequency of food presentation, increased effort, a higher response ratio requirement, longer delays to food, and so forth will all evoke the behavior that terminates such stimuli. These events have in common a form of worsening, and stimuli positively correlated with such events are often called conditioned aversive stimuli, without specifying any particular behavioral function. It is possible that these stimuli will generally function as CEOs in evoking the behavior that terminates themselves, as conditioned punishment (S^p) for any behavior that precedes their onset, and as

[12] The term *discriminated* arose so that this type of procedure could be distinguished from an avoidance procedure with no programmed exteroceptive stimulus except for the shock itself. It also implies that the warning stimulus is a *discriminative stimulus* for the avoidance response, but the main point of the present section contradicts this practice; thus, we should develop a new name for this type of procedure. Sometimes this procedure is called *avoidance without a warning stimulus* and is then contrasted with *avoidance with a warning stimulus.* This may be preferable to *discriminated,* but it implies the effect of the stimulus on the organism—it warns the organism—and it would be preferable if the terms for procedures did not presuppose their behavioral functions.

conditioned elicitors (CEs) for smooth muscle and gland responses of the same type that are produced by painful stimuli. And, of course, the offset of such stimuli will function as reinforcement (S^r) for any behavior that precedes that offset. As mentioned above in connection with the term *aversive stimulus,* there are advantages and disadvantages to such omnibus terms, and in any case their availability does not obviate the necessity for more specific terms. With respect to the CEO, the case can be most clearly stated as follows: Any stimulus condition whose presence or absence has been positively correlated with the presence or absence of any form of worsening will function as a CEO in establishing its own termination as effective reinforcement and in evoking any behavior that has been so reinforced.

It may be useful to repeat the argument against such stimuli being considered as discriminative stimuli. A discriminative relation involves a correlation with the availability of a type of consequence given a type of behavior. A correlation with availability has two components: An effective consequence (one whose EO was in effect) must have followed the response in the presence of the stimulus, and the response must have occurred without the consequence (which would have been effective as reinforcement if it had been obtained) in the absence of the stimulus. The correlation between the warning stimulus and consequence availability fails in the second component. In the absence of the warning stimulus, there is no effective consequence that could have failed to follow the response in an analogue to the extinction responding that occurs in the absence of an S^D. The fact that the avoidance response does not turn off the nonpresent warning stimulus is in no sense extinction responding, but rather is behaviorally neutral, like the unavailability of food reinforcement for a food-satiated organism.

Now consider a stimulus that is positively correlated with some form of improvement. Such a stimulus would clearly function as conditioned reinforcement (S^r) for any response that preceded its occurrence, but that is not the functional relation under consideration. Its CEO effect consists of its establishing its own offset as effective punishment and suppressing (as an opposite to "evoking") any behavior that has been so punished. The relation is quite plausible, although I know of no research that is directly relevant. Stimuli that are negatively correlated with some form of worsening (safety signals) have the same status as those that are positively correlated with improvement. Their onset would be expected to establish their removal as a form of punishment and to suppress any behavior that had been so punished. Similarly, but in the opposite direction, a stimulus that has been negatively correlated with improvement would be expected to establish its removal as reinforcement and evoke behavior that has been followed by such reinforcement. None of these last relations have been verified directly by research but seem to follow naturally from existing knowledge.

There is an important additional requirement involved in the correlation histories discussed above. It is essential for the stimulus not only to have preceded the worsening or improvement but also for removal of the stimulus to have systematically prevented the worsening or improvement. If removal of the stimulus does not prevent the worsening or improvement, there is no correlation (D'Amato, Fazzaro, & Etkin, 1968; see also Fantino & Logan, 1979, pp. 273–275).

Transitive CEO: Conditional conditioned reinforcement and punishment. When a stimulus condition (S1) is correlated with the correlation between another stimulus (S2) and some form of improvement (or worsening), the presence of the S1 establishes the reinforcing (or punishing) effectiveness of S2 and evokes (or suppresses) the behavior that has been followed by that reinforcement or punishment. Again, this relation has not been directly researched, but it follows easily from existing principles and concepts. Many (probably most) forms of conditioned reinforcement or conditioned punishment are themselves conditional upon other stimulus conditions. This notion is sometimes referred to by saying that conditioned reinforcing effectiveness is dependent upon a "context."

Imagine a food-deprived animal in an environment in which it can always produce a 10-s buzzer sound by pressing a lever. Distinctive visual stimuli are related to the relation of this auditory stimulus to food. In the presence of a red overhead light, the 10-s buzzer sound ends with the delivery of food. In the absence of the red light, the buzzer sound lasts for 10 s and then ends without any food delivery. This is a situation in which the auditory stimulus functions as a conditioned reinforcer, but is conditional upon the color of the overhead light. Thus the buzzer onset is not effective as reinforcement until the red overhead light comes on. When it does, with a well-trained animal, the lever press will be evoked. What is the reinforcement for the lever press? Obviously the buzzer onset. How does the red overhead light evoke the lever press? Not as an S^D, because it is not correlated with availability of the buzzer—the buzzer is actually available irrespective of the light condition, but it is not an effective form of reinforcement in the absence of the red light. It evokes the lever press as a CEO, a stimulus change that alters the reinforcing effectiveness—the *value*—of the buzzer sound and evokes the behavior that produces it. Only in the red light has the buzzer been paired or correlated with food, so only in the red light is it an effective form of conditioned reinforcement. The basic relation is still that of correlation, but of a more complex type. The buzzer's correlation with food is itself correlated with the light color.

There have been several attempts to demonstrate this type of CEO with nonhumans (Alling, 1991; McPherson & Osborne, 1986, 1988). The experiments have in common the following arrangement. One stimulus condition, S1, can be produced in both the presence and absence of another stimulus condition, S2. Onset of the first stimulus systematically precedes food reinforcement in the presence of S2, but not in its absence. In other words, S1 onset should function as conditioned reinforcement, but is conditional upon the presence of S2; it is thus a form of conditional conditioned reinforcement. The stimulus upon which its reinforcing effectiveness is conditional is the supposed CEO. Pigeons learn to stop producing S1 except in the presence of S2, but in the experiments cited above it has not been possible to exclude the possibility that S2 is simply functioning as the first discriminative stimulus in a two-response chain.

The first element in a chain evoked by an S^D is often a CEO of this type. Consider a rat in a chamber in which an auditory stimulus is related as an S^D to the availability of food for a lever press. But the lever cannot be pressed until it is located, so the auditory stimulus evokes visual search behavior, which is reinforced by seeing the lever. The auditory stimulus is not related to the availability of this reinforcement, however, but rather to its value. (Once the lever is seen, the other elements of the chain—approaching, touching, pressing—are controlled by a succession of S^Ds, but the first element is not.) Similarly, in an avoidance situation, the warning stimulus evokes the avoidance response as a reflexive CEO, but if this requires locating an operandum, the visual search behavior is evoked by the warning stimulus as a transitive CEO, which is correlated with the *value* of seeing the lever, not the availability of its sight.

This type of CEO is exemplified by many human examples. A workman is disassembling a piece of equipment. His assistant hands him tools as he requests them. In the process of disassembling, he encounters a slotted screw that must be removed, and requests a screwdriver. The sight of the slotted screw "evoked" the request, the reinforcement for which is receiving the screwdriver. To refer to the slotted screw as an S^D for the request, however, raises the same difficulty as before. This stimulus has not been differentially correlated with successful requests—screwdrivers are not more available when slotted screws are around than in their absence, but rather more valuable. The slotted screw should be considered a CEO for the request, not an S^D. Here the slotted screw is like the red light. In its presence, screwdrivers have been correlated with successful disassembly and are therefore valuable.

Another common human example is a stimulus related to some form of danger, in its evocation of protective behavior. A night watchman patrolling an area hears a suspicious sound and pushes a button on his radio phone that causes the other night watchman to answer the phone and ask if help is needed. The suspicious sound is not an S^D in the presence of which such help is more available, but rather more valuable. Note that this effect of the danger signal is not to produce its own termination, but rather to increase the value of some other event.

This type of analysis seems to be required irrespective of the direction of the first or second correlations, and irrespective of whether the final event is improvement or worsening. To consider one more example, let the buzzer be a stimulus that is negatively correlated with a worsening of some sort, in other words, let the buzzer be a safety signal; but let this correlation be in effect only when the overhead light is red. Under other stimulus conditions, the buzzer is uncorrelated with any form of worsening. Now let the lever press be a response, maintained by an unrelated form of reinforcement, that has in the past also terminated the buzzer, and thus in the red light terminated the "safety," a form of conditioned punishment for the lever press. The lever press, of course, also terminates the buzzer when the red light is not on, but in this case it is not punishment, because in the absence of the red light the buzzer is uncorrelated with worsening. We would expect that when the red light came on and the buzzer was on, any tendency to press the lever would be "suppressed." The red light functions as a CEO to cause buzzer offset to function as effective punishment and to suppress any behavior that has been so punished. These higher order relations may not play a major role in the typical experiment with nonhumans because they require such extensive histories. However, they would be expected in the repertoires of long-lived species in their natural environments, and most certainly in those of humans.

General Implications

Motivation as a topic within behavior analysis can be reintroduced as consideration of those variables—establishing operations—that momentarily alter the effectiveness of other events as reinforcement (and punishment) and simultaneously alter the frequency of those types of behavior that have been followed by that reinforcement (or punishment). A clear distinction is possible between motivative and discriminative variables in terms of whether they are related to the reinforcing effectiveness of an event or to its availability. The application of this distinction is especially critical for the proper interpretation of some of the effects of painful stimulation. When applied to learned functional relations, this distinction permits classification of a number of seemingly discriminative relations as conditioned establishing operations, further enlarging the topic of motivation within behavior analysis and facilitating useful identification of the various factors involved in the multiple control of human behavior.

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