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MULTISCALE BEHAVIOR ANALYSIS AND MOLAR BEHAVIORISM: AN OVERVIEW

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In the context of evolutionary theory, behavior is the interaction between the organism and its environment. Two implications follow: (a) behavior takes time; and (b) behavior is defined by its function. That behavior takes time implies that behavioral units are temporally extended patterns or *activities*. An activity functions as an integrated whole composed of parts that are themselves smaller-scale activities. That behavior is defined by its function implies that behavior functions to change the environment in ways that promote reproductive success. Phylogenetically important events (PIEs) are enhanced or mitigated by activities they induce as a result of natural selection. Induction explains all the phenomena that have traditionally been explained by reinforcement. This multiscale view replaces discrete responses and contiguity with multiscale activities and *covariance*. A PIE induces operant activity as a result of covariance in the form of a feedback relation between the activity and the PIE. A signal (conditional inducer) induces PIE-induced activities as a result of covariance between the PIE and the signal. In an ontological perspective, behavior is a process, and an activity is a process individual. For example, ontological considerations clarify the status of delay and probability discounting. A true natural science of behavior is possible.

Key words: molar behaviorism, multiscale behavior analysis, time allocation, phylogenetically important event, induction, contingency, class, individual, process

This paper aims to bring together a few disparate lines of thought into a single cohesive framework for behaviorism and behavior analysis. I originally called the view I was developing "molar" behaviorism, but came to discover that the label "molar" was misleading, because people seemed to assume it only applied to phenomena at long time scales and could not apply to phenomena at short time scales. Following Phil Hineline's suggestion, I began calling it the "molar multiscale view," with the intention that I would eventually just call it the "multiscale view." By 2013, in a paper, "What counts as behavior: The molar multiscale view," I was able to put together the time-based view with scale, choice, and evolution. Much of what I have to say has appeared before in print in various places, but I will try in a brief space to weave together the concepts and observations of those earlier writings. The following section summarizes the main concepts of multiscale behavior analysis and the topics I will enlarge upon in the paper.

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Prolegomenon

The importance to behavior analysis of making contact with evolutionary theory can hardly be overstated. Behavior analysis is properly part of biology. It is not a part of psychology, but an alternative to psychology. For psychology, behavior is a superficial phenomenon that must be understood by inferences to a "deeper" level: the mind or the brain. As long as behavior is not considered a subject matter in its own right and behavioral phenomena are considered secondary, a true natural science of behavior is impossible. Biologists often are naïve about the mind and consciousness, but they have no trouble thinking about behavior as real and primary. When asked, biologists whom I have met agree that behavior is an organism's interaction with the environment.

The organism is not the agent of its behavior, but the medium of its behavior. Organisms and behavior go hand in hand, because they both enhance the fitness of the genes that promote them. Organisms and behavior would not exist if the genes making for organisms were not selected by having greater reproductive success as a result of being located in organisms.

The connection to evolution and natural selection allows a rethinking of the concept of reinforcement. Once we recognize that ethologists' "fixed action patterns" and the notion of

operant behavior are equally relevant to understanding behavior, we can bring the two together, as Segal (1972) showed, with the concept of *induction* (Baum, 2012a; Tinbergen, 1963). Events impacting fitness, *phylogenetically important events* (PIEs), induce activities that enhance good (fitness-increasing) PIEs and mitigate bad (fitness–reducing) PIEs and also induce operant activities correlated with these PIEs. The operant activities that produce or avoid the PIEs are induced along with the unconditionally induced activities, including fixed action patterns. An activity may be called an "operant" activity to the extent that its ontogeny and maintenance depend on feedback between that activity and the inducing PIE. Events correlated positively with PIEs become proxies for them and induce many of the same activities as the PIEs themselves induce.

Multiscale Behavior Analysis

At the beginning of the twentieth century, scientists studying behavior relied on only two concepts: reflexes and associative bonds. Both concepts entailed discrete events and contiguity between the events. Pavlov's (1960) conditional reflexes (called "conditioned" due to a translating error) depended on contiguity between a conditional stimulus and an unconditional stimulus (which he also called a "reinforcer"). Pairing the two stimuli was supposed to result in a bond between the conditional stimulus and a conditional response. Before Pavlov, nineteenth-century philosophers and psychologists considered ideas to be connected by associative bonds. The associative bond, when combined with the reflex, became a bond between stimulus and response, or an S–R bond. Ethologists invented a similar concept, in which a sign stimulus was said to "release" a fixed action pattern (Tinbergen, 1963). Thus was born the vocabulary of stimulus, response, and reinforcer.

The early behaviorists Watson (1930) and Thorndike (2012) theorized about S–R bonds. Although Watson considered S–R bonds sufficient, Thorndike added to the associative laws, such as the law of contiguity, another law, which he called the "law of effect." According to the law of effect, an S–R bond is strengthened when a satisfying event closely follows the S–R sequence.

Skinner (1938) introduced a new concept with his invention of operant behavior. In 1938, he tied it to the reflex, but he soon recognized that operant behavior cannot be characterized by S–R bonds, because no identifiable stimulus precedes each occurrence of the response. He followed with two innovations: (a) measuring behavior as response rate; and (b) stimulus control. With these two new concepts, Skinner left S–R bonds behind. Instead, he thought of response rate as the primary measure of behavior, and a discriminative stimulus as exerting "control" by modulating response rate. Thus, stimulus control replaced the eliciting of the response by the stimulus that characterized the reflex. Skinner's innovations pointed in a direction away from discrete responses and contiguity, but he never made a further move in that direction because he never went beyond the "operant" as a class of discrete responses or the theory that an immediately following reinforcer "strengthens" an operant response.

Critique of the Molecular View of Behavior

The view that behavior consists of discrete responses that are strengthened by closely following (contiguous) reinforcers may be identified as the *molecular* view of behavior (e.g., Skinner, 1948). It seems to explain the observation that response rate increases when responses produce reinforcers (e.g., food). That is about all it explains, however. It does not explain even the most basic phenomena in behavior analysis. For example, the molecular view cannot explain why ratio schedules maintain extremely high response rates, whereas interval schedules maintain response rates that are moderate—that is, lower but not extremely low (e.g., Baum, 1993). In attempting to explain the rate difference, molecular theorists cite differential reinforcement of relatively long interresponse times (IRTs) on interval schedules. Morse (1966), for example, showed that on an interval schedule IRTs followed by a reinforcer generally exceed IRTs not followed by a reinforcer. The reason is that the longer the IRT, the more likely an interval will have timed out during the IRT, setting up reinforcer delivery for the next response. Differential reinforcement of long IRTs explains why rate on an interval schedule

should be lower than rate on a ratio schedule, because IRT is the reciprocal of response rate.

One trouble with this IRT theory is that it predicts something incorrect. If the key to lower rate on interval schedules is that the probability of reinforcer delivery increases as IRT increases, then IRTs should increase until the probability equals 1.0. For every response to produce a reinforcer, response rate on an interval schedule would have to be extremely low, but response rates on interval schedules, though lower than rates on ratio schedules, are still moderately high. When I have pointed out this theoretical failure, some molecular theorists answer by suggesting that such long IRTs would tend to increase the interreinforcer interval. That is so, but it is not part of the theory. In particular, because IRT is the reciprocal of response rate, and interreinforcer interval is the reciprocal of reinforcer rate, the suggested addition actually introduces an extended relation between response rate and reinforcer rate.

The moderately high rates on interval schedules cannot be explained without reference to reinforcer rate. When response rate is low on an interval schedule, increases in response rate produce large increases in reinforcer rate. As response rate rises to moderate levels, reinforcer rate ceases to increase. This relation is captured in the interval schedule's feedback function, which is negatively accelerated and approaches an asymptote (Baum, 1992).

Not only does the IRT theory fail to explain why interval response rates are as high as they are, it also fails even more obviously to explain the extremely high rate on ratio schedules, because in a ratio schedule, no relation exists between IRT and reinforcer probability. When one considers that the feedback function for a ratio schedule is simply an increasing straight line, an explanation in more extended terms appears. Increases in response rate always increase reinforcer rate; the only limit is the organism's ability to respond quickly. Someone trying to defend IRT theory might point out that, typically, responding occurs in bursts alternating with pauses, and on a ratio schedule a high-rate burst may be more likely to produce a reinforcer than responses spread out in time (i.e., low rate). Such an explanation departs from IRT theory, however, by pointing to differential reinforcement of response rate. It also implies that high response rates shorten the interval between reinforcers—which is to say that high response rates increase reinforcer rate, because the interreinforcer interval is the reciprocal of reinforcer rate. Not differential reinforcement of IRTs, but differential reinforcement of response rate by increasing reinforcer rate explains the extreme response rates that ratio schedules maintain.

Another phenomenon that molecular theory cannot explain is negative reinforcement, particularly avoidance. Suppose Tom, a divorced man with a grown son, Sam, receives a phone call from Sam inviting Tom to his wedding. Tom declines the invitation because Sam's mother, Tom's ex-wife, will be at the wedding, and Tom doesn't want to see her. Thus, Tom avoids his ex-wife, but why? Declining the invitation produces no immediate reinforcer; it only insures that something will not happen. The molecular view has no way to explain this, because it cannot appeal to any immediate reinforcer, although so-called "two-factor theory" would postulate an implausible and invisible "fear" of the ex-wife that is reduced by the declining. Instead, we can view Tom's declining as part of an extended pattern of avoiding his ex-wife: he not only turns down invitations to events at which she will be present, but he in general avoids places where she might be. He might not always be successful, but his avoidance activities reduce the likelihood that he will have to see her.

This explanation of Tom's behavior jibes with the explanation of free-operant avoidance in the laboratory. Sidman (1966) suggested that rats press a lever that postpones electric shock because pressing the lever reduces the rate of shocks received. Herrnstein (1969) elaborated on this appeal to extended relations and pointed out the inadequacy of the molecular view as adopted by Skinner and some other behavior analysts. Another view, also based on extended relations, explains avoidance as due to induction of the operant activity by failures—shocks received or encounters with the ex-wife—rather than shock-rate reduction (Baum, 2018).

Some behavior analysts, notably Herrnstein and some of his students (e.g., Hineline, 2001, and Rachlin, 1994, 2014), moved ahead in the direction that Skinner had pointed out—toward temporally extended phenomena and theories. A major step was the discovery of the

matching relation (Herrnstein, 1961). Generalizing this discovery leads to a law of behavior: the Law of Allocation.

The Law of Allocation

As Herrnstein (1961) originally presented it, the matching relation stated that the proportion of behavior allocated to an alternative tended to match the proportion of reinforcers obtained by that alternative:

$$\frac{B_1}{B_1 + B_2} = \frac{r_1}{r_1 + r_2}, \tag{1}$$

where B_1 and B_2 are rates of behavior allocated to Alternatives 1 and 2, such as pecking at two response keys, and r_1 and r_2 are the rates at which reinforcers, such as bits of food, are obtained. Equation (1) represented a major step, because it introduced reinforcer rate as a valid independent variable for understanding response rate. Just as Skinner had recognized an extended measure, response rate, as a dependent variable, the matching relation introduced an extended measure, reinforcer rate, as an independent variable, and together they indicated that behavior and its controlling relations could be seen as extended in time.

Herrnstein (1970) generalized Equation (1) to any number, N, of alternatives:

$$\frac{B_j}{\sum_{i=1}^{N} B_i} = \frac{r_j}{\sum_{i=1}^{N} r_i}. \tag{2}$$

Equation (2) goes beyond the original observation (Eq. (1)) to state a law. It builds on the insight of the necessity of temporal extension to offer a more general framework.

From the recognition that the matching law implies temporally extended variables and relations, only a short step was required to write matching more generally in terms of time (Baum & Rachlin, 1969):

$$\frac{T_j}{\sum_{i=1}^{N} T_i} = \frac{V_j}{\sum_{i=1}^{N} V_i}, \tag{3}$$

which states that the proportion of time taken up by one activity j matches V_j relative to the total of V_i across all alternatives, and each V_i is a composite measure of reinforcer variables, such as rate, amount, and immediacy, that determine the relative time. This is truly a law, and is a tautology, as all laws are (Rachlin, 1971). Equation (3), perhaps, might be called the "generalized matching law," but that term nowadays denotes a more specific version, even though that equation is not really a law in the usual sense, but an empirical generalization (Baum, 1974, 1979; Poling, Edwards, Weeden, & Foster, 2011). Though I originated the equation, I did not name it as such, but the usage has become common (Poling et al., 2011).

Equation (3) may be rewritten in a variety of ways (Baum, 2012b), but it is general enough for present purposes to be called the Law of Allocation. It has been used to explain impulsive choice (Aparicio, Elcoro, & Alonso-Alvarez, 2015) and resurgence—the reappearance of extinguished responding when an alternative activity is extinguished (Shahan & Craig, 2017). These applications draw on the implication that no activity exists apart from the context of other, competing, activities. If one activity increases, others must decrease, and if one activity decreases, others must increase. Extinction, for example, consists of a shift from an allocation high in operant activity to one that includes little of the operant activity (Baum, 2012c).

Like any scientific law, the law of allocation embodies and depends upon a number of assumptions or axioms. They might be taken as guidelines for experimenting and theorizing about behavior. These were discussed less formally in an earlier paper (Baum, 2013; see also Baum, 2018).

Axiom 1: Only whole organisms behave. Axiom 1 applies to all organisms: multicellular—humans, dogs, pigeons, fish, cockroaches, or hydras—and unicellular—paramecia or amoebae—and archaic—bacteria and viruses. As we will see below, these are all individuals that interact with their surrounding environment.

For behavior analysis, Axiom 1 excludes inanimate things, because behavior analysis deals with living organisms. An exception might be robots with artificial intelligence, if their interactions with the environment become too complex to predict from their programmed algorithms.

In associating behavior only with whole organisms, Axiom 1 rules out behavior by parts of an organism. My heart's beating may be part of my physiology, but it is not part of my behavior. In particular, Axiom 1 denies that the brain behaves (Bennett & Hacker, 2003). Bennett and Hacker (2003) explain the logical reason that only whole organisms behave. For example:

> Psychological predicates are predicable only of a whole animal, not of its parts. No conventions have been laid down to determine what is to be meant by the ascription of such predicates to a part of an animal, in particular to its brain. So the application of such predicates to the brain … transgresses the bounds of sense. The resultant assertions are not false, for to say that something is false, we must have some idea of what it would be for it to be true—in this case, we should have to know what it would be for the brain to think, reason, see and hear, etc., and to have found out that as a matter of fact the brain does not do so. But we have no such idea, as these assertions are not false. Rather, the sentences in question lack sense. (p. 78).

According to multiscale behavior analysis, what Bennett and Hacker (2003) say in this quote about "psychological predicates" applies to behavior in general, not just thinking, reasoning, seeing, and hearing. To speak of the behavior of parts of living things—anything other than whole living organisms—"transgresses the bounds of sense." The brain does not perceive, choose, or sense, any more than the brain can walk or talk; these are activities of whole organisms. In this view, the brain is an organ of the body and participates in behavior, but does not behave itself.

A more important reason for Axiom 1 derives from evolutionary theory. From the perspective of evolutionary theory, behavior only exists because organisms exist. Organisms exist because the genes that make for organisms reproduce more successfully than competing genes that would undo organisms—that is, the genes that produce and reside in organisms have higher fitness than any competitors. The competition continues now, just as long ago. Multicellular organisms continually face challenges by less organized life forms, particularly bacteria and viruses. These threats are countered by evolved mechanisms, such as the immune system, symbiosis with micro-organisms in the gut and on the skin, and practices such as treating water before drinking it. The success of the organism-making genes relies on the organism's interaction with the environment around it, because the organism's actions change the environment in ways that are, on average, advantageous to survival and reproduction. Often the environmental changes feed back to affect the organism's further actions. The organism's actions are the organism's behavior. (See Baum, 2013, for further discussion.)

Axiom 2: To be alive is to behave. Axiom 2 says that so long as an organism is alive, it behaves continually. It immediately implies that behavior takes up all the time available. If one observes an organism for an hour, a day, or a year, one observes an hour's worth, a day's worth, or a year's worth of behavior. If behavior is allocated among various activities, those activities each take up some of the time, and together take up all of the time. Moreover, time is limited. Every living thing lives within a time budget, because lifetimes are finite, a day contains just 24 hours, and opportunities for behavior are ephemeral. As a result, activities compete with one another for time, in accord with Equation (3). The key task of behavior analysis is explaining the allocation of time among all the organism's activities.

The connection to evolution further supports the central principle that behavior takes up time, because interaction with the environment can only take place over time. The phrase "momentary interaction" is an oxymoron, because interaction can only be extended. That behavior cannot occur at a moment tells us that the historical concept "momentary response" was logically and theoretically flawed.

Indeed, no activity can be identified at a moment. A snapshot of a person holding an open book tells almost nothing about what activity is occurring; the person might be reading, looking for something in the book, pretending to read, and so on. Only by observing for some time, before and after the moment, can the activity be identified as reading or

pretending or something else. Similarly, a snapshot of a rat with its paws on a lever tells almost nothing of what activity is occurring; one has to see what went before and what came after to decide if the rat is pressing the lever at a high rate, at a low rate, pressing at all, exploring the chamber, or something else. (See Baum, 1997, 2013, for further discussion.)

The impossibility of identifying behavior at a moment implies that attempting to explain behavior at a moment is not only unrealistic or quixotic, but also impossible. Behavior is continuous—a flow—not a series of momentary discrete "responses." The only discrete events might be switches from one activity to another, and perhaps those might be predictable. For the rest, explaining and predicting behavior consists of explaining and predicting the amount of time spent in various activities, on whatever time scale works.

Viewing behavior as consisting of discrete responses leads inevitably to hypothetical constructs that can only mislead. For example, Killeen and Jacobs (2017) argued for the importance of considering an organism's physiological state in predicting its behavior, but they moved from physiological states to "dispositions" as causes of behavior. A disposition is nothing, however, if it is not behavior. Physiological states may be measured, but a disposition that does not result in measurable action is a phantom. The rate at which an activity occurs *is* its disposition to occur. Attributing the activity to its disposition is circular and is a category mistake (Ryle, 1949).

One might assert the converse of Axiom 2 also: To behave is to be alive. Not only bacteria, which have a cell or plasma membrane, are considered alive because they reproduce and interact with the environment around them—secreting chemicals, attacking cells, and exchanging genetic material—but also viruses, naked molecules lacking any membrane, are considered alive because they reproduce in and interact with the bacteria and cells they encounter. Prions, smaller protein molecules that only replicate, are not considered to be alive. Thus, behavior is inextricably tied up with life and characterizes what are considered "live organisms."

Axiom 3: Every activity is composed of parts that are themselves activities. Axiom 3 introduces scale into Equation (3). It says that the time taken up by any one activity may be subdivided into the less-extended, smaller-scale activities of which it is composed, and that the time taken up by those parts adds up to the time taken up by the more-extended, longer-scale activity of which they are parts (Baum, 1995a; Baum & Davison, 2004). If I play tennis for an hour, during that hour I am serving shots, returning shots, keeping score, exchanging remarks with my opponent, and so on. Together these activities constitute playing tennis, and together they take up the whole hour of my playing tennis. If a pigeon pecks at keys in concurrent schedules, its performance has parts: pecking at the right key, pecking at the left key, and background activities other than pecking. Its pecking might be organized into long visits to the preferred key ("fixing" on the rich key) alternating with brief visits to the nonpreferred key ("sampling") plus background activities (Baum, 2002; Baum, Schwendiman, & Bell, 1999). Thus, Equation (3) may apply at any time scale, to the parts of playing tennis or to the activities of a day, one of which is playing tennis, and to the allocation of pecking between keys or to the pattern of pecking and switching between keys. It may apply even at time scales of fractional seconds, to the parts of a pigeon's key peck or a rat's lever press (e.g., Smith, 1974). Axiom 3 underpins what I call multiscale behavior analysis. (See Baum, 2018, for further discussion of laws of behavior.)

The Behavior-Environment Feedback System

Some earlier papers suggested that the interaction of behavior with the environment may be compared to a feedback system (Baum, 1973, 1981, 1989, 2016). To say that behavior interacts with the environment implies that behavior and environment constitute a feedback system. Figure 1 shows a diagram of the feedback system for one activity. It depicts a simplification, because no one activity can be isolated from others. (A more detailed attempt may be found in Baum, 1981, Fig. 1.) "Competition" appears in the role of a set-point, but cannot be thought of as a set-point in the same sense as a thermostat's set-point. Instead, competition from other activities constrains the effect of fed-back events in r on activity B. Competition accords

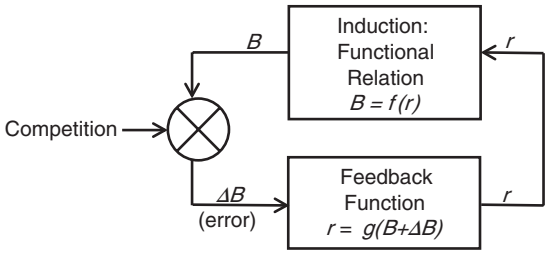

Fig. 1. Behavior and environment as a feedback system. The Law of Allocation ("Competition;" Eq. (3)) determines the set-point. A feedback relation in the environment translates error (ΔB) into a PIE rate (r). An induction relation through the organism translates r into rate of the operant activity (B), as, for example, in Equation (4).

with the Law of Allocation; one may think of it as Equation (3). It incorporates the current rate of the activity, B, and the deviation or "error" equals ΔB, which is input to an environmental relation. The function g represents a feedback function—a property of the environment. The output of the feedback function, r, is a rate of consequences, PIE rate (e.g., food rate). The rate r is input to an organism-based functional relation and represents induction, discussed below. Some evidence suggests that this relation may be a power function, at least for relating food rate and pigeons' rate of key pecking (e.g., Baum, 2015; Baum & Davison, 2014):

$$T_j = b_j r_j^{s_j} \tag{4}$$

where T_j is time spent pecking, r_j is rate of food, s_j is sensitivity of T_j to r_j, and b_j is a coefficient. Equation (4) states that r_j induces time spent pecking according to the power s_j and in proportion to b_j. In principle, r_j need not be only rate of food; for example r_j could represent amount of food or immediacy of food (Baum & Rachlin, 1969). Equation (4) combined with Equation (3) results in an extremely general version of the Law of Allocation (Baum, 2012b).

The function f in Figure 1 may be thought of as Equation (4), with B equal to T_j. The system stabilizes when ΔB equals zero. That equilibrium is often called "stable performance." Although local variation never ceases, allocation may be considered stable when it ceases to exhibit a trend across time (Baum, 2017c).

One might notice that the model in Figure 1 omits anything that might be called "reinforcement." It approaches a stable, but variable, state, but nothing like strength appears in the model, any more than a thermostat controlling the temperature in a room entails strengthening of room temperature. Induction replaces reinforcement. For this reason, some researchers have suggested that matching, as embodied in Equation (3), is "unconditioned" or "innate" (Gallistel et al., 2007; Gallistel, Mark, King, & Latham, 2001; Heyman, 1982). Behavior is selected, but by competitive induction, not by strengthening.

As a model of behavior, Figure 1 is extremely general. To apply it to any particular situation, one must decide how to measure feedback r and activity B. A number of researchers have suggested various approaches to measuring r when it refers to PIE ("reinforcer") rate. Gallistel and associates suggested an algorithm that examines cumulative records to estimate reinforcer rate, change in reinforcer rate, and abrupt changes in responding (Gallistel et al., 2001, 2007). Davison and I, using pigeons, were able to examine short-term effects of individual food deliveries (Davison & Baum, 2000). Examining transitions from one long-term concurrent schedule pair to a new pair, I found that, after sufficient feedback—food deliveries—from the new schedule pair, transitions in behavior were abrupt (Baum, 2010; Baum et al., 1999).

The need to invent ways to estimate the controlling variable r leads to a question: If we discover a method of estimating r that successfully predicts some behavior, does that mean the organism also uses that method? Although no warrant exists to make such an inference, some researchers seem to make it nonetheless. Gallistel, for example, writes that the organism under study makes the computations, rather than his algorithm (Gallistel et al., 2001, 2007). Shahan (2017) wrote, "… having something somewhere accumulated or stored up—such preservation is a logical and physical necessity for solving the problem of bringing the past into the present" (pp. 111-112). No physical necessity exists, because we have no idea as yet how the past is brought into the present or even if that is the correct way to think about the past; the method that the physiology of the organism uses may have nothing to do with

accumulating or storing. The necessity might be "logical" in the sense that bringing the past into the present *means* accumulating and storing, but that makes Shahan's reasoning circular. The experimenter estimates the variables and, with luck, finds some order.

Multiscale Behavior Analysis and Evolutionary Theory

Axiom 3 above introduces the fundamental property of scale. If driving to work is part of working, then driving to work occurs on a smaller time scale than working. One may say that working takes longer than driving to work. Driving to work is an activity composed of yet shorter activities such as driving on the highway and driving on town roads (see Wallace, 1965 for a detailed discussion of driving to work). Variation in an activity consists of variation of its parts. Some days I may drive to work by the highway and other days by back roads; sometimes I may drive at high speed other times at low speed.

At the longest time scale for an individual organism, only one activity occurs. We may call it "living." Recalling the logic of evolutionary thinking, according to which multicellular organisms only exist because of the success of the genes they carry, we may conclude that living serves one function: reproducing. All other activities, whatever their scale, are ultimately parts of reproducing. In particular, surviving is often a necessary part of reproducing. Exceptions exist—for example, male mantids and spiders that are eaten by the female after copulation, providing a good meal for the female that benefits the male's offspring. Parents of many species sometimes risk their own lives for the sake of their offspring. Individuals of our own species, which is uniquely cooperative, sometimes even risk their lives for complete strangers.

Surviving is a necessary part of reproducing the same way that getting out a mixing bowl is necessary to making a cake; the longer-scale activity cannot be completed without it. Though necessary, however, surviving is not sufficient for reproducing. Other parts, like mating and caring for offspring, more directly related to reproducing, must also occur. Surviving only has to provide opportunities for these other parts of reproducing on average and in the long run. Evolutionary arguments always contain this proviso, either explicitly or implicitly. A beneficial gene may be selected in a population even though some members of the population possessing the gene die without reproducing, because the gene confers advantage to offspring on average and in the long run. Similarly, an operant activity may be selected even though its consequences are sometimes bad if the consequences are better than competing variants on average and in the long run. Camping outdoors may usually be an exhilarating experience, but sometimes is ruined by a rainstorm; people still go camping. Indeed, an activity may be maintained that only serves a function in the long term, but serves no function each time it occurs (Rachlin, 1992). For the sake of my dental health, I brush my teeth every morning and night, even though, on a daily basis, the activity is just an effort that takes up time.

The perspective offered by evolutionary theory, that organisms exist to reproduce, may be summarized as, "Organisms are the means by which DNA makes more DNA." It helps to answer many questions about life in general and human life in particular. For example, why do organisms age and die? Lifespan is tied to generation time; once a generation of parents has produced offspring, the parents may no longer have a function and, rather than live on and compete with their own offspring, they die—genes are selected that result in this built-in obsolescence. Human beings present a challenging puzzle: the phenomenon of menopause. In most species, both males and females continue to be fertile as long as they live, but in our species only the males remain fertile. A possible reason lies in the uniquely long period of dependence of our offspring. This dependence creates a "grandmother effect," in which menopause may be selected by its benefit to women's genes in their grandchildren. If a woman ceases reproducing and helps care for her grandchildren, her genes may be more likely to be passed on through the grandchildren. Genes making for this pattern would be selected if the beneficial effect on the grandchildren outweighs any advantage of producing more offspring.

Evolutionary theory helps to understand why many human activities exist that otherwise would have no explanation. Even though activities like art, music, and religion might seem to have little connection to reproducing, they can be fitted into the larger context of

evolution. A highly social species like ours lived all its evolutionary history in groups, and many shared practices (i.e., operant activities), collectively known as "culture," belong to the group (Baum, 2017a). Some practices serve the individual person's reproductive success, and some practices serve the group as a whole. Avoiding poisonous plants serves the individual, but ingroup–outgroup discrimination serves only the group as a whole. Art, music, and religion may provide ways to enhance one's status within a group and thereby open opportunities for mating and gaining resources. Practices with less-obvious function often serve the group as a means of maintaining group cohesion—for example, wearing certain tattoos or clothing, speaking a certain language dialect, and attending a certain church. Since group membership is fundamental to human life and survival, most human activities tie less directly to reproducing than to surviving.

Surviving, like any other activity, has parts. The parts are not always easy to identify as such. In the past, I suggested three long-scale human activities: maintaining health, gaining resources, and maintaining relationships (Baum, 1995b, 2017a). All three promote survival, and this division is useful for discussion, but these parts sometimes overlap. One usually needs to be healthy to gain resources, and sometimes resources make for good health. Earning a living by holding a job requires getting enough sleep, but having income allows one to have the shelter needed to get enough sleep. Relationships may help with gaining resources, but sometimes resources allow formation of new relationships. A friend may lend you money, but having money also may open doors that might otherwise be shut. Despite the overlap, Axiom 2 above tells us that behavior takes up all the time available and cannot take up more time than is available. The overlap, along with Axiom 2, leads to what may be called the "accounting" problem—that is, the problem of deciding when one activity begins and another leaves off in order to measure the time spent in each activity.

The Accounting Problem: Defining and Measuring Activities

In the laboratory, we can arrange conditions so as to prevent overlap between activities. We define activities so that they are readily measured. For example, research with concurrent schedules has produced support for viewing choice as allocation of time among activities. An experiment by Bell and Baum (2017) studied concurrent variable-interval (VI) variable-ratio (VR) schedules of key pecking in pigeons. Although the two types of schedules maintained qualitatively different patterns of pecking, Bell and Baum were able to measure the time spent at each alternative, and the time allocation between them provided the best description of the choice relations as relative reinforcers obtained varied across the alternatives. The accounting problem appears to be solved because no pecks are possible at one key while pecking is occurring at the other key.

Yet, even in the laboratory ambiguity arises. As Herrnstein (1970) noted, a pigeon in an experimental chamber is not limited only to pecking keys. Every organism brings with it unmeasured activities like grooming, scratching, and exploring. That is why he added a term r_o to the version of Equation (1) that described responding at a single programmed alternative. Subsequent research indicates that such "background" activities separate into those that are induced by the reinforcer (PIE; e.g., food) and those that occur independently of the reinforcer. Analysis by Davison (2004) suggests that several different background activities occur alternately.

The accounting problem is less challenging in the laboratory than in more naturalistic settings, with humans or other animals, inside or outside the laboratory. When doing research, one must define activities so that they are mutually exclusive. Once the definitions are clear, one may tackle measurement. The best approach is to record behavior and have two or more observers code the videographic recordings (e.g., Simon & Baum, 2017). That approach, however, is labor-intensive. Another approach with humans is self-report; one simply asks a person how much time they spend in various activities, but this method relies on people to be accurate in their estimates.

Defining activities. Skinner (1938) introduced the definition of operant activity by its function. Evolutionary theory explains why definition of behavior by function is indispensable. Because the function of organisms is to reproduce, behavior exists ultimately as

interaction with the environment in the service of that function. Behavior consists of activities that serve functions that ultimately serve reproducing. Thus, when a rat's lever pressing produces food, that activity may serve the function of feeding (along with other parts, like consuming the food); pressing the lever is then part of feeding, and feeding is essential to surviving and reproducing.

In more naturalistic situations, defining activities depends on deciding which functions they serve. Depending on one's research interest, having lunch with a friend may be construed as an activity that maintains a relationship—a variant of socializing—or as an activity that maintains health—a variant of eating. A third possibility, if one wanted to separate socializing from eating, would view having lunch with a friend as multitasking (Baum, 2013). Research on multitasking indicates that it entails rapid switching back and forth between two activities (resulting in poorer performance on both than either by itself; e.g., Caird, Willness, Steel, & Scialfa, 2008).

Proper definition of activities allows one to study practical problems. For example, suppose one wished to study work–life balance in someone's life. Defining "work" and "life" plausibly would be crucial. If the two activities occur in two different locations, definition might be relatively simple. Even then, however, overlap might occur, as when a person gets a work-related phone call at home or a family-related phone call at work. Defining the activities so that they are mutually exclusive might be a bit inaccurate; the more natural the setting, the lower tends to be the accuracy with which it can be studied.

Measuring activities. For measuring activities, we gain clarity by distinguishing between episodes and constitutive parts. All activities are episodic. Suppose I drive to work every weekday. Each drive to work is an episode of the activity "driving to work." All the episodes of driving to work over the course of a month or a year together constitute an aggregate, which we may liken to a population. In evolutionary theory, the aggregate of members of a species makes a population. One may be interested in the population as a whole—its size and geographical distribution—or one may be interested in the variation across the members of the population—their physical characteristics or reproductive success. Similarly, one may be interested in the population of episodes of an activity—their number or total—or one may be interested in variation across episodes—their duration or their constituent parts. If I were just interested in the aggregate, I might want to know how much time I spend driving to work. If I were interested in the variation among episodes, I might note that some of my drives to work include driving through Smithtown (a part), whereas others might avoid Smithtown. At a smaller time scale, I might be interested in the population of my drives through Smithtown—for example, some might adhere to the speed limit whereas others might exceed the speed limit, attracting the attention of local police.

In laboratory research on behavior, populations and episodes are modeled by measuring bursts, bouts, or visits (e.g., Aparicio & Baum, 2006, 2009; Baum, 2017c; Baum & Davison, 2004; Bell & Baum, 2017; Shull, Gaynor, & Grimes, 2001). Operant activity, like all behavior, divides into bouts interspersed with pauses that represent time spent in other activities (Davison, 1993; Gilbert, 1958). Those bouts or visits may be thought of as episodes of the operant activity, and their aggregation constitutes a population. One might examine the variation in their duration for clues to initiation and termination of the bouts, or one might examine their function, as in the pattern called "fix and sample" (Baum et al., 1999), in which operant activity fixes on the richer of two choice alternatives and takes the form of brief samples at the leaner of the alternatives.

Laboratory research also occasionally raises variation in constituent parts of patterns of operant activity. An example may be seen in food-induced activities that compete with the operant activity (e.g., Breland & Breland, 1961). These activities figure into Equations (2) and (3) and other expressions of the Law of Allocation. For example, Baum and Davison (2014) factored in induced activities to explain apparent deviations from the matching law. Conceiving of behavior as composed of multiple activities provides a plausible and elegant approach to measuring behavior.

Reinforcement and Induction

For over 100 years, a common interpretation of reinforcement was that reinforcers increase the "strength" of responses that

produce them. Questions about this interpretation arose from time to time and increasingly in the 1970s. The conception that behavior consisted of discrete responses seemed to require the concept of strength, because explaining an increase in rate of a discrete response through time seemed to require some hypothetical temporally extended variable. When we move to conceiving of behavior as composed of temporally extended activities, however, the increase involved in "reinforcement" may be seen as an increase in the amount of time taken by an activity that produces the "reinforcers." If a rat is trained to press a lever, the activity of lever pressing takes up more time than before training. The need for "strength" disappears. The activity simply increases.

Explaining the increase in behavior without reference to strength invites relating such increases to evolutionary theory. If we think of an organism interacting with its environment, certain events hold special significance because they relate relatively directly to surviving and reproducing. These events may be called "phylogenetically important" because they impact reproductive success (fitness). A good phylogenetically important event (PIE) promotes fitness by its presence (e.g., mates, prey, and shelter). A bad PIE threatens fitness by its presence (e.g., predators, illness, and parasites). These PIEs need to be responded to well for a species to thrive. Individuals that respond in ways that enhance good PIEs like feeding or mating opportunities and avoid bad PIEs like predators or toxins are more likely to survive and reproduce than their less-adept conspecifics. Hence, we expect that selection will result in populations of organisms that respond to PIEs in certain reliable ways (Baum, 2012a).

Some authors have misinterpreted the concept of PIE, confusing "phylogenetically important" to mean locally efficacious. For example, Killeen and Jacobs (2017) argued for the need to introduce an organism's current physiological state into our analyses of behavior, because an organism exposed to the same contingencies may nevertheless behave differently at one time than another, depending on its physiological state. If you have just eaten a big meal, you are unlikely to act so as to eat more, but when you haven't eaten for several hours, you willingly take on more food. Discussing this, Killeen and Jacobs (2017) write that when in a certain state, a "consequential response, R_C … will be a *satisfier* (Thorndike)—an *important event* (Baum)" (p. 20; italics in the original). Removing the adverb "phylogenetically" creates ambiguity about the meaning of "important." Later, Killeen and Jacobs confuse the meaning further:

> 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 induction (p. 26; italics in the original).

Cowie and Davison (2016), who generally include the adverb "phylogenetically," fall into the same ambiguity, writing, "… environmental events may, under current organismic conditions, be PIEs that are currently important to the organism (events such as food and water may not always be important, but pain is always important)." (p. 265.) No doubt the organism's physiological state is important to predicting when an organism will initiate feeding on a small time scale, but the meaning of "important" in "phylogenetically important" depends on a much longer time scale. Let us consider a couple of illustrative examples.

A pride of lions, having just gorged on a kill, now ceases hunting. After some days, the lions' physiological states have changed, and now they hunt again to feed again. Songbirds in winter must take in enough food during the day to last through the night. When starving, they shift from being risk-averse to risk-prone (Krebs & Kacelnik, 1991).

On one time scale, feeding for the lions and the birds is cyclic. For the lions the cycle occurs across several days; for the birds one day. Feeding depends on the passage of time, and as time passes hunting or foraging becomes more likely, which is to say that the PIE becomes locally efficacious; the passage of time or the physiological state—if we could measure it—induces the activity that produces the PIE. The relation between time and feeding, however, is local and within an organism's lifetime, whereas the relation between feeding and surviving occurs on the time scale of phylogeny. Lions must eat enough to survive, and selection favors those lions that hunt effectively and hunt when they are hungry; the

others are selected against. As a result of natural selection, lions will both hunt effectively and hunt when they haven't eaten for some days. Similarly, a songbird that fails to decrease risk-sensitivity when starving is less likely to survive, and phylogeny results in birds that make the shift. Feeding is phylogenetically important in this sense: surviving (and reproducing) depend on feeding. A phylogenetically important event is an event that has been important across generations of lions, birds, and other species. As a result, a PIE, when efficacious, induces its PIE-related activities.

What sorts of events are phylogenetically important? An earlier paper suggested that they are the events traditionally thought of as reinforcers, punishers, and unconditional stimuli (Baum, 2012a). Premack (1965, 1971) argued that the events are behavioral events, that reinforcers and punishers are behavior of high and low probability. Logic and research indicate that Premack's generalization does not always hold. Under most circumstances, we assume that food must be eaten to function as a PIE, but experiments on "latent learning" in rats show that food uneaten may nevertheless change behavior later when the rats are hungry and eat the food (Kimble, 1961). This delayed change is not unusual. Many mammals and birds cache food for later consumption, sometimes months later (Krebs & Davies, 1993). Experiments on "sensory preconditioning" (Kimble, 1961) suggest that so-called "neutral" stimuli—tones and lights—may not be neutral, particularly if one considers that organisms may depend on signals in their environment to find food or avoid predators. Experiments with "sensory reinforcement" further support the non-neutrality of "neutral" stimuli, because they show that a variety of visual, auditory, and tactile stimuli may function as reinforcers (Kish, 1966).

Premack's generalization particularly falls short with aversive, bad PIEs, such as electric shock (injury), illness, and predators. These would be stimuli, not behavior. They happen to an organism, and they induce avoidance or defense, rather than consummatory behavior.

Events that are phylogenetically important may be behavioral events, like eating, drinking, and mating, but they may also be stimuli, like food (prey), water, and a mate. They may function as traditional reinforcers and punishers, but from the perspective of multiscale behavior analysis, they function as inducers, either inducing appetitive activities or avoidance. Premack's (1971) generalization falls short because it lacks any connection to evolutionary theory, which incorporates PIEs of all sorts.

As an explanation of behavior, the concept of reinforcement was always incomplete. The question remained, "Where did the behavior to be reinforced come from?" Segal (1972) proposed the concept of induction to explain the provenance of the to-be-selected behavior and, at the same time, integrate operant behavior with PIE-induced behavior (also known as "adjunctive," "interim," and "terminal"). A PIE like food or a mate induces a suite of activities like capture and consumption (food) and arousal displays and courtship (a mate). Thus, if a resting hungry pigeon starts to receive bits of food, the pigeon becomes highly active and, among other activities, it pecks. A hungry rat treated this way also becomes active and, among other activities, noses around in the food hopper. Pigeons explore and exploit food sources in their natural environment by pecking (typically seeds, but sometimes bread and even chicken bones on city streets). Rats explore and exploit food sources in their natural environment by nosing and chewing. PIEs that are crucial to an organism's surviving and reproducing in its natural environment induce activities relevant to the PIEs. Thus, phylogeny is crucial for understanding species-typical behavior, but phylogeny is also crucial for understanding ontogeny of behavior in individual organisms.

In explaining provenance of operant behavior, induction indicates that induced activities provide the "raw material" for selection to act upon (Segal, 1972; Staddon & Simmelhag, 1971). One implication is that variation is neither "undifferentiated" nor "minimal," as Skinner (1984, p. 670) suggested in one article, but rather follows the "natural lines of fracture," as Skinner (1935/1961) suggested elsewhere. A PIE induces a variety of whole extended activities that are not random with respect to the PIE, but rather are the result of phylogeny. Timberlake (1993) gave a similar view with his concept of behavioral system, which refers to all the various activities induced by a PIE.

Relating induced activities to operant behavior requires only one further step: recognizing

the role of contingency or, more generally, *covariance*. Skinner (1948) regarded close temporal proximity of a reinforcer following a response as the relation that increases the rate of a response. Subsequent research showed that contiguity is neither necessary nor sufficient. Studies of delay showed contiguity is not necessary for reinforcement (e.g., Baum, 1973; Lattal & Gleeson, 1990). Studies in classical conditioning and adjunctive behavior in which contiguity is decoupled from contingency indicate that contiguity is not sufficient to explain response increase (e.g., Rescorla, 1968; Staddon & Simmelhag, 1971). Instead, Rescorla (1967), discussing proper controls for classical conditioning, pointed out that a contingency required that two events both occur together and be absent together. In most experiments with classical conditioning, this requirement is met by comparing what happens in a trial with what happens in the intertrial interval. In a trial, a conditional stimulus (CS) occurs along with an unconditional stimulus (US), whereas in the intertrial interval both are absent. The CS is something like a tone, and the US is something like food, a PIE. In classical conditioning, the key requirement is that a CS should covary with a PIE. In positive covariance, they should be absent and present together or, more generally, their rates should vary together. In negative covariance, the inverse should hold. Operant conditioning relies on covariance in which the PIE depends on the activity, and the covariance may be positive or negative too (Baum, 2012a; 2018). In a feedback relation, as the rate of the activity varies, the rate of the PIE increases or decreases with it.

What is true for a CS is also true for a discriminative stimulus (S^D): The S^D comes to increase the rate of an activity because it covaries positively with a PIE. A tone that covaries with food takes on some of the functions of food; in particular the tone induces many of the same activities that the food induces. Thus, positive covariance between a stimulus (S^D or CS) and a PIE changes the function of the stimulus to resemble that of the PIE (Davison & Baum, 2010).

A question arises about a stimulus (CS or S^D) that becomes such a proxy for a PIE: How similar is the behavior induced by the proxy to the behavior induced by the PIE itself? Is this concept a resurrection of Pavlov's (1960) discredited theory of stimulus substitution? Pavlov's theory required that the conditional response and unconditional response be identical, a prediction that was often refuted (Kimble, 1961, pp. 204-205). Whether the activities induced by a CS or S^D are the "same" as those induced by the PIE itself is, at least to some extent, an empirical question. Not all activities induced by a proxy are identical to those induced by the PIE, but some undeniable resemblances occur. A few observations may serve to clarify. First, however, one must distinguish induction from elicitation. Although food may elicit salivation, the activities that food induces go beyond salivation. For example, Zener (1937) noted that unrestrained dogs responded in a variety of ways to a tone paired with food, particularly by approaching the food bowl. A rat or pigeon cannot eat in the absence of food, but food, presented either contingently or noncontingently, induces food-related behavior between presentations, and some of this behavior is directly included in eating. Breland and Breland (1961) observed this, and laboratory research (Staddon, 1977) shows that rats and pigeons fed periodically or irregularly in an experimental chamber engage in activities that are parts of feeding—for example, drinking (rats) and pecking (pigeons). In a striking demonstration, Jenkins and Moore (1973) reported that when a key light is paired with food, pigeons peck at the key as they would when eating grain, but when the key light is paired with water, pigeons operate the key with motions like those of drinking. In the days when they were made of brass, response levers became green and encrusted with rats' dried saliva and often had to be replaced as they were gradually chewed away.

When we come to operant behavior, the activities induced by a discriminative stimulus are hardly distinguishable from the activities induced by food. That is why we say the S^D "modulates" response rate. If pecking at a green key sometimes produces food, and pecking at a red key does not, the green key induces pecking, just as the food does. Resemblance occurs also in operant avoidance. Regardless of what reflex responses may be elicited by an aversive PIE, the PIE will induce avoidance if avoidance is possible (Baum, 2018; Sidman, 1966). If a signal covaries positively with an aversive PIE, the signal induces

avoidance—for example, in a shuttlebox—("negative reinforcement;" Baum, 2012a). If the signal induces avoidance, however, the activity it induces is the activity that avoids the PIE, not the signal (Herrnstein, 1969); Tom avoids his ex-wife, not his son.

What I call "proxies" of a PIE depend on positive covariance with the PIE, but negative covariance matters also. If a pigeon is trained to peck at a green key and not at a red key, the red key covaries with food negatively. The red key induces activities other than pecking (Baum, 2012a; Staddon, 1982; White, 1978). Food itself may covary negatively with food, as when food production alternates between two alternatives (Cowie & Davison, 2016). Similarly, if a signal covaries negatively with an aversive PIE, the signal may be called "safety" and induces activities other than those induced by the PIE, including avoidance.

Event–event covariance is one important sort of covariance affecting behavior; as indicated earlier, the other is PIE-activity covariance. When the rate of a PIE depends on the rate of an activity, as in a "reinforcement schedule," the activity (e.g., lever pressing) comes to be induced by the PIE (e.g., food or electric shock; Baum, 2018). In other words, the activity becomes operant activity. We know that operant activity is induced by the PIE from observations such as reinstatement, in which noncontingent presentation of the PIE revives an extinguished activity (Reid, 1958). The lever pressing produces the food, the food induces the lever pressing, which produces the food, and a feedback loop occurs that selects lever pressing out of all other activities and maintains lever pressing at a high level. As Figure 1 indicates, depending on the shape of the feedback function, the maintained rate will be extreme on a ratio schedule, which imposes a linear feedback function, but moderate on an interval schedule, which imposes a feedback function with an upper limit to PIE rate (Baum, 1993; 2015).

Figure 2 diagrams the relation between a PIE and its induced activities. On the left, a PIE (*S*; e.g., food) occurs in the environment (*E*) and impinges on the organism (*O*). Several activities are induced, including one labeled *B* (e.g., touching a lever) and others that compete for time with *B*, labeled B_O. On the right of Figure 2, a contingency has been introduced that makes *B* produce the PIE.

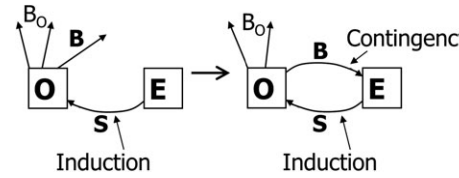

Fig. 2. Contingency closes a loop. Left: Without any contingency, the environment provides a phylogenetically important event (PIE; *S*), which impinges on the organism (*O*) and induces several activities *B* and B_O. Right: A contingency arranges that *B* produces the PIE and closes a loop, in which the PIE induces *B*, and *B* produces the PIE. The other activities denoted as B_O continue to be induced and compete with *B*.

Now the loop is closed, and the PIE induces *B*, *B* produces the PIE, and the PIE covaries with *B*. *B* was not initially operant activity, but has become operant and can now be shaped by changing the requirements for it to produce the PIE. The diagram shows, however, that the PIE still induces the activities denoted as B_O. They may still compete for time with the operant activity *B*, as indicated in Figure 1. Observation and theory support the assumption that the other activities compete with the operant activity (Baum, 2015; Baum & Davison, 2014; Breland & Breland, 1961; Herrnstein, 1970).

Thus, covariance explains both conditional induction by a CS or S^D and conditionally induced (operant) behavior. A full theory of behavior will take into account phylogenetic sources of behavior such as PIEs and the activities they induce, and also event–PIE covariance (i.e., signaling) and activity–PIE covariance (i.e., feedback).

Instead of using "operant" as a noun, we may use it as an adjective and recognize that activities may be partially the result of development and partially operant. Activities given by development often are refined by feedback (e.g., Hailman, 1969; Tinbergen, 1963). In humans, verbal behavior offers a striking example, because infants respond to others' vocalizations from birth and later imitate the vocalizations they hear (e.g., Moerk, 1992). Induction is nowhere more relevant than in verbal behavior. When Ben and Jan are in conversation, Ben's utterances induce Jan's utterances and vice versa. Much remains to be understood about conversation (e.g., Simon & Baum, 2017).

Patterns of behavior—activities—repeat from time to time. When an activity is

maintained, the PIEs that maintain it not only follow the activity, but precede it. The distinction between consequence and antecedent collapses, because the occurrences of the PIE keep the activity going in the way that a flywheel on an engine keeps the engine going. The inducing PIEs accompany the activity rather than precede or follow it. The PIE and the activity engage in a feedback loop, as in Figures 1 and 2.

New activities enter behavioral allocations with some frequency. In nonhuman animals, they enter by imitation and other accidents. In humans, they enter mainly through rule following, when a rule (a verbal discriminative stimulus) induces some novel action on the part of a rule-following person (Baum, 1995b, 2017a). When I start playing tennis, that activity becomes a regular part of my weekly activities. It repeats, and the Law of Allocation tells us that it must displace some other activities.

The complexity of human behavior in the everyday world presents a challenge for behavior analysis. The concepts developed within a science of behavior should apply readily to human behavior. The Law of Allocation makes a start, because it illuminates the way people spend time, problems like "work–life" balance (Baum, 2017a), and some forms of psychotherapy (Córdoba-Salgado, 2017). Induction allows us to think about behavior that we call "rational" and also behavior we call "irrational" or "emotional" (Segal, 1972). In contrast with the molecular view, concepts like induction and temporally extended activities begin to allow constructing explanations and treatments that are plausible and functional.

The Ontological Status of Activities

The central precept in multiscale behavior analysis is that the units of behavior are temporally extended. Other features, such as the matching law or the Law of Allocation stem from this concept. Apart from the inadequacy of the molecular view of behavior, two grounds for adopting the central precept appeared earlier: (a) that the interaction between the organism and the environment cannot be observed at a moment; and (b) that no behavior can be defined at a moment (Baum, 1997, 2013). The first is a theoretical argument, and the second is epistemological. I believe one may also derive the temporal extension of behavioral units more directly on ontological grounds. If so, behavioral units must be temporally extended.

Two ontological distinctions are helpful in thinking about activities: (a) between objects and processes; and (b) between classes and individuals (Baum, 2017b). They are not entirely independent of one another, but I will take up each in turn.

Object versus Process

In everyday parlance, an object is any distinctive feature of the world that is seemingly stable—a tree, a house, a river, a star. Their apparent relative stability translates into repeatability, as when I return to a room I left yesterday and find that all the objects are still in their places. Their repeatability arises because they may be labeled and classified. Atomic particles, for example, may be classified according to their energy levels. To the extent that discrete responses are treated as repeatable and classified according to fixed criteria, discrete responses are treated as objects. If a response is classified as any movement that depresses a lever a certain distance and with a certain force, the response is being treated as an object. Behavior, however, manifestly constitutes process.

In contrast with the stability of objects, processes are changes through time—movement, deterioration, transformation, metamorphosis, growth. Some objects undergo notable change and are spoken of that way, as when we speak of a child becoming an adult. When we recognize that behavior is interaction with the environment and that behavior takes time, we recognize that behavior is process. A rat's lever pressing, a child's crying, a person's reading—these are processes, although their full definition as activities requires incorporation of their functions. The rat's lever pressing might be part of feeding, the child's crying may serve to summon a caretaker, and the person's reading might serve to inform. Thus, activities are processes.

Like any process, an activity may occur for longer or shorter time intervals. I may read a book for one minute or one hour. No matter how brief a bout of lever pressing—even if it results in only one operation of the lever—lever pressing still entails movement and takes

time; lever pressing is still a process and not a discrete response (Baum, 1976).

Class versus Individual

A class singles out objects or processes according to a set of defining attributes. Dog is a class of which specific concrete dogs are instances; my dog Fido is an instance. Deterioration is a class of which the wear and tear on my house and the progress of a disease are instances. Skinner's (1938) definition of an operant as a class meant that the movements that met the criteria of the class were instances of the class.

Classes cannot change and cannot do anything. They may have more or fewer instances, but they are fixed by their defining attributes. Change the force required for a lever press, and you change the class. A class cannot do anything, because it is an abstraction; only concrete particulars can do things. "Dog" cannot come when I call, but my dog Fido can come when I call. An operant, as a class, cannot do anything; only the concrete movements that are instances can get a lever pressed.

In contrast to classes, individuals can change while still retaining their identity. An individual could be either an object or a process. An individual is a concrete particular with parts that function together as an integrated whole and is situated in time and space. Classes are eternal, whereas individuals have beginnings and endings. Whereas classes have instances, individuals have parts. The relation between instance and class contrasts with the relation between part and whole; individuals are instances, but they have no instances. Individuals can be described, but they cannot be defined. Abraham Lincoln was an individual, and my dog Fido, but also the chair on which I am sitting and the Rocky Mountains; they are all concrete particulars, they all function, and they all have integral parts that function together. Although organisms are spoken of as individuals, they are not the only ontological individuals. A baseball team is an individual, insofar as the players function together and win or lose as a whole. As Ghiselin (1997) explains, species are individuals; their members are their parts, and their function is to evolve.

Processes occur in individuals. When an individual changes, the individual goes through a process. Abraham Lincoln grew from a baby into a boy and into a man. When we talk about behavior, however, our language for talking about processes may be misleading. When we say Abraham Lincoln grew, we mean only that the process of growth occurred in him. When we say that Rat 5 pressed the lever, we also should mean only that lever pressing occurred in Rat 5—yet an additional element creeps in: agency.

When we say that Abraham Lincoln delivered the Gettysburg Address, from the perspective of a science of behavior we mean that the speech delivering occurred in Abraham Lincoln. Confusion might exist if one thought that Lincoln's growing was a different sort of process from Lincoln's speech delivering because Lincoln did not *do* the former, whereas he *did* the latter—that is, the speech delivering involved agency. (See Baum, 1995c, for further discussion of agency.) Recalling that behavior is interaction with the environment, we may think of the organism as the medium of its behavior—thus, if we are trying to be precise and avoid confusion, we might say the behavior occurs *in* the organism. Of the many meanings of "in," the usage here is that in phrases like, "a statue cast in bronze" or "an agreement in writing" or "Speak in English." We don't usually speak about behavior this way, because the usual construction of saying, "The organism did such-and-such," is so familiar.

As behavior, activities are processes that occur in organisms. Not all processes that occur in organisms are activities, only the ones that affect the environment. The heart's beating, though essential to keeping the organism intact, is not behavior, because the heart is only a part of the organism (see Axiom 1 above) and does not affect the environment. Putting on a coat to stay warm counts as an activity, because staying warm is an interaction with the environment. Tom's avoiding his ex-wife is an activity, because it functions to keep him from seeing her.

An earlier paper (Baum, 2002) suggested that activities themselves may be seen as individuals (Baum, 2017b). Like any other individual, an activity is an integrated whole constituted of parts that work together to serve a function. As cells constitute an organ, and organs constitute an organism, an activity like playing tennis is constituted of activities:

serving, returning, keeping score, and so on. The activity lever pressing is both a process that occurs in Rat 5 and an individual constituted of parts that are also activities—pawing the lever, biting the lever, licking the lever, and so on. The activity baking a cake is both a process that occurs in the baker and an individual constituted of parts that are also activities—getting out a bowl, adding ingredients, mixing, and so on. Thus, an activity is both a process and an individual—a process individual.

Why Ontology Matters

The insight that behavior is process and consists of activities that are process individuals offers the third of three arguments mentioned earlier against viewing behavior as composed of discrete responses and in favor of temporally extended units. This ontological argument concludes that process implies temporal extension and change, neither of which is captured by discrete responses that are instantaneous and unitary. Because behavior is process, its units must be temporally extended.

As an example, consider discounting, the idea that distant and uncertain rewards are less valued than immediate and certain rewards (e.g., Green, Myerson, Oliveira, & Chang, 2014; Odum, 2011). In a study of discounting, a person is given a series of binary choices, from which a number of indifference points between immediate small amounts and delayed large amounts are derived. These indifference points are plotted as a function of delay or odds-against, and either a hyperbolic function is fitted to the points or the area under the connected points is estimated. Either way, the method results in a measure of the relative steepness of the curve. Thus, discounting is a measure, not a process. This prompts the questions: What does discounting measure, and what process is involved?

The participant's behavior is the process: choosing or expressing preferences. The preferences may be indicative of the participant's preferences in everyday life. Discounting, as an index, measures choice—time allocation—between two extended patterns of behavior—that is, two activities. One activity, often called "impulsivity," pays off in the short term, but is punishing in the long term. The other activity, often called "self-control," is punishing in the short term, but pays off in the long term (see Baum, 2016, for further explanation). As the value-laden terms "impulsivity" and "self-control" suggest, allocation of time to the short-term-advantageous activity (e.g., drunkenness, smoking, overeating, selfishness) is assumed to be problematic. The long-term-advantageous activity (e.g., sobriety, healthy eating, cooperation) is assumed to be desirable. Thus, interventions aim to increase time allocation to "self-control," while (necessarily) decreasing time allocation to "impulsivity." This explication of discounting becomes clear only in the light of the insight that behavior consists of process individuals—that is, temporally extended activities with parts.

Molar Behaviorism

Behaviorism is the philosophy that underpins a science of behavior. The central premise in behaviorism is that a science of behavior is possible (Baum, 2017a). If a science of behavior were impossible, behaviorism would be unnecessary.

A science of behavior may be made impossible in a variety of ways. In psychology, the supposition that behavior is not a subject matter in its own right would make the science impossible. Particularly the assumption that behavior is done by an agent—an inner self, the mind, or the brain—makes the science of behavior impossible. Indeed, any notion that behavior is caused by internal, unobservable entities, such as a person's inner intentions, beliefs, desires, or thoughts, makes the science impossible or, at least, incoherent. Behaviorism may be called "radical" because it rejects inner causality and agency, and instead places causes in the environment.

Skinner (1945) made a mistake when he advanced private events to account for thoughts and feelings. He was responding to the criticism that behaviorism ignores the most important part of human life, our inner thoughts and feelings. He would have done better to challenge the traditional view that our behavior is caused by thoughts and feelings and to have stayed with the view that the origins of behavior (its "causes") always lie in the past and present environment. He and other behaviorists tried to save the inferences to private events by calling them "interpretation." Such "interpretation" bears no resemblance to explanation in

other sciences, which always refer to empirical relations verified in observation. Skinner's "interpretations" resemble not science, but poetry or literature.

Private events seem to be of two sorts: (a) subvocal speech (Watson, 1930, pp. 238-243); and (b) sensing or imagining. Almost anyone can talk to himself or herself without others hearing, and almost anyone can see images or hear sounds that others cannot. Artificial intelligence programs coupled with brain scans may render these private events, at least in part, to be no longer private, but public. Once our subvocal speech becomes public that way, it will become data—events to be explained. In ordinary circumstances, however, private events remain private and can only legitimately be offered as part of an explanation of behavior once they have been made public in those circumstances with instrumentation (Baum, 2011). For example, we usually look to environmental conditions to decide if a person is lying, because usually only those are available, but if a computer and brain scan were able to give reliable indicators, we would have more evidence to bring to bear.

In contrast with private events, private stimuli do not exist. Positing private stimuli as causes of behavior denies the science of behavior, because science requires that causes be observable. For example, a person or animal said to be "in pain" exhibits pain behavior (Rachlin, 1985). The pain behavior is a response to a physical condition of the body, usually an injury. Pain fibers in the nervous system are stimulated when the skin is breached, or a muscle is strained, or a tooth is decayed, or the brain receives excessive blood flow, or a nerve is pinched. All these conditions are observable, if not with the unaided senses, then with the right instruments. If the pain is genuine, pain behavior is caused by the stimulation of the pain fibers. When a dog limps and whimpers, we look for a thorn in its foot. The injury is the cause of the limping and whimpering, not "pain," not a private stimulus. Similarly, when a person limps and says, "I have a pain in my foot," the cause of the limping and saying (if genuine) is the injury, not a private stimulus called "pain." The temptation to attribute behavior to private stimuli derives from everyday talk about behavior, but for a science of behavior private stimuli are unobservable causes. The everyday mistake that a science must avoid is inferring private stimuli from behavior and then, circularly, using them to try to explain behavior. When at a party Jan says to her husband Ben, "I'm tired; let's go home," she is not reporting on a private stimulus; her utterance comes from a long history with such utterances and their effects (perhaps escaping from uncomfortable situations). Verbal behavior depends primarily on the presence of a listener who is likely to respond; other aspects of the context may be important, too, but combine with the primary context. Jan may or may not be tired, just as someone may be in pain or fake being in pain; the listener's sympathetic response is what counts. Verbal behavior, like all other behavior, occurs because of past and present environment, not thoughts and feelings. (See Baum, 2011, for further discussion of private events.)

A true natural science of behavior is possible, a science that makes no appeal to unobserved inner events or hypothetical inner objects or processes like response strength and inner computing. Such a science may be achieved by accepting that all behavior and the environmental covariances that affect it are extended in time. For example, if activity–PIE covariance turns an activity into an operant activity, we may not know the physiological mechanisms that make this possible, but nothing stops us from studying the dependence between the activity, which is measurable, and the covariance, which is also measurable. Measures based on information theory offer one possibility to measure covariance (Shahan, 2017). The physiology may follow and be far different from anything we could guess.

In a natural science of behavior, behavioral events are natural events. Natural events are explained by their relation to other natural events. For example, an increased frequency of hurricanes in the Caribbean is related to changes in water temperature, which are related to increased global temperature (i.e., climate change). Natural events, if thought of as "caused," are caused by other natural events.

In particular, natural events are not caused by agents; natural events just happen, they are not done by anyone (Baum, 1995c; Skinner, 1971, pp. 7-14). When a stone falls, it accelerates as it approaches the ground. No physicist

today would say the stone accelerates because it (privately) wants to reach the ground. Saying it accelerates because of gravity would also be a mistake, because the acceleration is an example of gravity, and making gravity a cause would make it an unseen agent—committing what Ryle (1949) called a "category error." Similarly, no behavior analyst should say that a rat presses a lever because it has "memory" that pressing the lever produces food. The rat's pressing results from the past covariance between pressing and feeding, which was observable, in contrast to its inner "memory," which is not. As with gravity, one could say at best that the rat's lever pressing *is* its memory. The rat does not do anything, because it is only the medium of its behavior. No more than the rat, are we the doers of our deeds.

Conclusion

Behavior takes time. This fundamental principle for understanding behavior is supported by logic, by theory, and by research. Its implications are profound. It puts aside the traditional molecular view based on discrete events and contiguity. It tells us that behavior must be understood as dynamic and extended in time, an insight that concurs with the view of behavior implied by evolutionary theory, that behavior is an organism's interaction with its environment.

Molar behaviorism and multiscale behavior analysis treat behavior as consisting of activities that are extended in time. They treat behavior at any time scale, whether milliseconds or years. An episode of an activity like a pigeon's peck, however brief, has temporal extent. Care should be taken to avoid confusing brief episodes of an activity with discrete responses; they are qualitatively (ontologically) different concepts.

Activities are processes and individuals. They function as integrated wholes and evolve through time as their parts (less extended activities) change through time and take up more or less time. Like species, activities have a beginning and may go extinct as other activities replace them—we change jobs, move to new neighborhoods, have children, and change spouses. This multiscale view applies plausibly both to behavior in the laboratory and to behavior in the everyday world.

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