Chapter 4
Introduction to Molar Behaviorism and Multiscale Behavior Analysis

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Brief Autobiography

I was born in New York City and grew up there. As a boy, I developed an interest in animals and their behavior. Over the years, besides dogs and cats, I kept fish, birds, turtles, and mice. When I was in high school, a family friend gave me two popular books about animal behavior, and I supplemented these with books I borrowed from the library. I conducted a study of the relation between maze-solving ability and social dominance in male mice in my bedroom, because neither facilities nor guidance was available at my school. I won a prize for my report from the New York State Board of Regents.

In my first year at Harvard College, I started concentrating in biology, because I assumed that was the right department for studying animal behavior, but in the spring of my freshman year, looking through the course catalog, I noticed “Nat. Sci. 114,” which included “behavior” in its title. I went to the first class, found it interesting, and enrolled in it. The professor was B. F. Skinner. The class was divided in half: one half read the textbook, *Science and Human Behavior*, and the other half did the material as programmed instruction on teaching machines. I was in the latter group and enjoyed learning from the machines.

Now alerted that courses on behavior were available in the psychology department, the next semester I enrolled in a course taught by R. J. Herrnstein. The material interested me, and I soaked it up, but on the first exam I wrote such long detailed answers that I didn’t finish all the questions. I went to see Herrnstein in his office, and he told me, “Just write faster.” After that, my performance was excellent, and Herrnstein noticed. He asked me about my concentration. After I told him I was concentrating in biology, he told me I should switch to psychology, because biology

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D. Zilio, K. Carrara (eds.), *Contemporary Behaviorisms in Debate*,
https://doi.org/10.1007/978-3-030-77395-3_4

required eight full courses, whereas psychology required only six, and I would be free to take courses in other areas.

I switched into psychology, and Herrnstein became my adviser. I took courses from him and other members of the department—including J. C. (Joe) Stevens and A. C. Catania. In those days, psychology at Harvard was considered a natural science, including sensory systems, behavior, and physiology. Avoiding the standard courses in psychology, in the Social Relations Department, suited me. In the summer after my junior year, S. S. Stevens and Joe Stevens hired me to work in the Psychophysics Laboratory. I ran experiments on sensory scaling and motor learning. In my senior year, I asked Herrnstein about doing an honors thesis. He suggested that I try an automated version of a T-maze to study choice in rats. He took me into one of the experimental rooms, showed me a relay rack, showed me how a relay worked and how to make a lockup, and then told me to learn how to program. I built a three-lever chamber with two dipper feeders for sucrose solutions of various concentrations and programmed various probabilities on the two choice levers. (The lever on the opposite wall initiated trials in which the rats pressed one of the choice levers.) My committee consisted of Herrnstein and S. S. Stevens, who grumpily acknowledged that I had done a good job and told me to get *Elements of Style*, by Strunk and White, so that I could learn to write better—in retrospect, this was a great compliment.

After graduating, I spent the summer in San Francisco painting and sculpting, and I enrolled in art school at New York University in the fall. My father, who was a painter, was dead set against my becoming an artist and urged me to choose science. By Christmas, I decided he was right. I dropped out of art school, applied for graduate school, and looked for work in science laboratories. I worked in a laboratory giving drugs to rats and extracting their pituitary glands and then in an experimental cardiac surgery laboratory.

In the fall of 1962, I entered the graduate program at Harvard University. The number of students admitted was unusually large, 12 or 13, although a few never finished. We had only two choices: psychophysics or behavior. I chose behavior, and Herrnstein became both my adviser and my mentor, and I began calling him "Dick."

The time was exciting. For me, a pivotal moment was the first time that, at one of our weekly research meetings, Dick drew on the blackboard a feedback function for a variable-interval schedule. Even before that, Howie Rachlin, Phil Hineline, and I began discussing the possibilities of the molar view of behavior, transcending momentary events and examining relations extended in time, such as between response rate and reinforcer rate. I found these discussions highly stimulating.

After completing my doctoral work, I spent a postdoctoral year at Cambridge University in the subdepartment of animal behavior studying reproductive behavior of canaries. I returned as a postdoctoral fellow to Harvard the following year, 1966. After some months, I was hired as a postdoctoral researcher with the responsibility to create a computer-based behavioral laboratory. I started teaching in 1967. In 1970, I was appointed assistant professor. From 1966 to 1970, Howie Rachlin and I were at Harvard together and collaborated.

Rachlin and I produced three papers in the molar framework, two published in (1969) and one in (1972). The 1969 paper, "Choice as time allocation," was soon declared a citation classic. In a paper that came out in 1973, "The correlation-based law of effect," I tried to lay out the basics of this new way of thinking about behavior.

In 1973, I still thought that the molar view and the molecular view of behavior could be complementary. By the mid-1970s, I began to see that the time-based view of behavior was incompatible with the traditional molecular view. A choice experiment with rats that came out in 1976 convinced me that timing activities rather than counting discrete responses made the most sense, even if counting microswitch operations provided reliable data. I reasoned that the switch operations roughly indicated the amount of time spent (Baum, 1976).

In 1975 and 1976, I spent 2 years as a senior researcher at the National Institutes of Health, at the Laboratory of Brain Evolution and Behavior, studying behavior of rats and mice living in colonies, with John C. Calhoun. After that, I went to the University of New Hampshire, where I remained until 1999, when I took early retirement and moved to San Francisco.

By 1995, I was able to articulate the concept of a temporally extended activity and the nesting of smaller-scale activities within any more extended activity (Baum, 1995a). The concept had two implications. First, I saw that the molecular view wasn't just inadequate but led to a completely implausible view of life outside the laboratory and, for that matter, wasn't much better even in the laboratory. My reasoning was buttressed by readings in philosophy, notably the writings of Benjamin Whorf and Erwin Schrödinger. Second, I began to see how the concept of scale was central to the molar view, but scale only became central in my writing in 2002, with the publication of "From molecular to molar: A paradigm shift in behavior analysis."

As the view developed further, I realized that the label "molar" was misleading, because people seemed to assume it only applied to phenomena at long time scales and couldn't apply to phenomena at short time scales. Following Phil Hineline's suggestion, I began calling it the "multiscale molar view," with the intention that I would eventually just call it the "multiscale view." I applied the concept of scale in analyzing data from experiments I was doing with Michael Davison and Carlos Aparicio at the time (Aparicio & Baum, 2009; Baum & Davison, 2004). 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.

The importance to behavior analysis of making contact with evolutionary theory cannot 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 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. Biologists who I talk to readily accept the idea that behavior is an organism's interaction with the environment.

The organism is not the agent of its behavior but the medium of 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" are just as relevant to understanding behavior as is the notion of operant behavior, we can bring the two together, as Segal (1972) showed, with the concept of *induction* (Baum, 2012a). 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. Events correlated with PIEs become proxies for them and induce the same activities as the PIEs themselves induce.

Molar Behaviorism

Behaviorism is the philosophy that underpins a science of behavior, which is usually called behavior analysis. The central premise in behaviorism is that a science of behavior is possible. If a science of behavior were impossible, behaviorism would be unnecessary.

A science of behavior could 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.

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 question 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 behavior analysts 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.

Positing private events as causes of behavior denies the science of behavior. 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 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. When Jane says to her husband Tom, "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 an uncomfortable situation). 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. 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.)

In a 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. When a stone falls, it accelerates as it approaches the ground. No physicist 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 "knows" that pressing the lever produces food. The rat's pressing results from its training, which was observable, in contrast to its "knowledge," which is not. As with gravity, one could say at best that the rat's lever pressing *is* its knowing. No more than the rat are we the doers of our deeds.

Multiscale Behavior Analysis

At the beginning of the twentieth century, scientists studying behavior relied on only two concepts: reflexes and associative bonds. Both entailed discrete events and contiguity between the events. Pavlov's (1960/1927) 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. Thus was born the vocabulary of stimulus, response, and reinforcer.

The early behaviorists Watson (1930) and Thorndike (2012/1911) 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 inventions: (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 doesn't 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. Since IRT is the reciprocal of response rate, differential reinforcement of long IRTs explains why rate on an interval schedule should be lower than rate on a ratio schedule.

The 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 inter-reinforcer interval. That is so, but it is not part of the theory. In particular, because IRT is the reciprocal of response rate, and inter-reinforcer 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. 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 to the molecular view as adopted by Skinner and some other behavior analysts. Baum (2020) introduced an explanation of avoidance that combines Sidman's insight with the induction of avoidance activity by the occurrences of the noxious event—avoidance is maintained by its failures.

Some behavior analysts, notably Herrnstein and some of his students (e.g., Hineline, Rachlin, and me), 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 law (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 law stated that the proportion of behavior allocated to an alternative tended to match the proportion of reinforcers obtained by that alternative:

$$\frac{B_1}{B_1 + B_2} = \frac{r_1}{r_1 + r_2}, \tag{4.1}$$

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, were obtained. Herrnstein (1970) generalized Eq. (4.1) to any number, N, of alternatives:

$$\frac{B_j}{\sum_{i=1}^{N} B_i} = \frac{r_j}{\sum_{i=1}^{N} r_i}. \tag{4.2}$$

The matching law 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 law 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.

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, 1974; Baum & Rachlin, 1969):

$$\frac{T_j}{\sum_{i=1}^{N} T_i} = \frac{V_j}{\sum_{i=1}^{N} V_i}, \tag{4.3}$$

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. V_i may be called the *competitive weight* of activity i. It represents the extent to which inducing events (PIEs) induce activity i (Baum & Aparicio, 2020; Baum & Grace, 2020).

Equation (4.3) 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 et al., 2015) and resurgence—the reappearance of extinguished responding when an alternative activity is extinguished (Shahan & Craig, 2017). Like any scientific law, it 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; unicellular, paramecia or amoebae; and archaic, bacteria and viruses. As we will see below, these are all individuals that interact with their surrounding environment.

Axiom 1 excludes inanimate things—stones, houses, automobiles, dead fish, or computers. These all undergo processes: they move, burn, break, decay, or calculate. These processes, however, do not entail interaction with the environment—the two-way street. Not all processes constitute behavior.

In associating behavior only with whole living organisms, Axiom 1 partially defines what we mean by "behavior." In addition to excluding inanimate things, it 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)

What Bennett and Hacker 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 inanimate things or 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. People sometimes speak of the brain as if it behaved, but such speech constitutes only metaphorical extension and clashes with logic.

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 microorganisms 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. 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.)

One might assert the converse of Axiom 2 also: to behave is to be alive. Not only bacteria, which have a cell 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 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 Eq. (4.3). 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. 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 non-preferred key ("sampling") plus background activities. Thus, Eq. (4.3) 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 the multiscale view of behavior. (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). Figure 4.1 shows a diagram of the feedback system for one activity. (A more detailed presentation may be found in Baum, 1981.) The set point of the system ("competition") accords with the law of allocation; one may think of it as Eq. (4.3). It is compared with the current rate of the activity, *B*, and the difference 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. 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 & Aparicio, 2020; Baum & Grace, 2020):

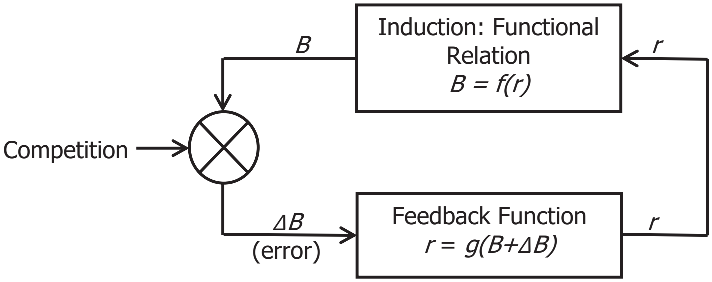

Fig. 4.1 Behavior and environment as a feedback system. The law of allocation ("competition," Eq. 4.3) determines the set point. A feedback relation in the environment translates error (ΔB) into a PIE rate (r). An induction relation through the organism translates r into rate of the operant activity (B), as, for example, in Eq. (4.4)

$$T_j = b_j r_j^{s_j}, \tag{4.4}$$

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 (4.4) 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).

The function f in Fig. 4.1 may be thought of as Eq. (4.4), with B equal to T_j. The system stabilizes when ΔB equals zero. That equilibrium is often called "stable performance." Although local variation never completely ceases, allocation may be considered stable when it ceases to exhibit a trend across time.

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).

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 will benefit the male's offspring. Even human beings sometimes sacrifice their own lives for the sake of their offspring.

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 always 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.

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? Life span 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 special puzzle: the phenomenon of menopause. In other 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 long period of dependence of our offspring. Rather than continuing to produce children that would compete with her other children, a woman may stop reproducing and continue living for the benefit of her grandchildren. Genes making for this pattern would be selected by the beneficial effect on the grandchildren.

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. 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 the group. Art, music, and religion may provide ways to enhance one's status within a group and therefore 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 has parts, like any other activity. 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, 2017). 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 Eq. (4.1) 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 alternatively.

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. Since 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. 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 et al., 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; Bell & Baum, 2017; Shull et al., 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. These activities figure into Eqs. (4.2) and (4.3) and other expressions of the law of allocation. For example, Baum and Davison (2014) factored in induced activities in order 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.

The Ontological Status of Activities

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

Objects Versus Processes

In everyday parlance, an object is any distinctive feature of the world that is seemingly stable—a tree, a house, a river, and a star. Their apparent relative stability translates into repeatability, as in sunsets or chemical reactions. Their repeatability arises because they may be named 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.

In contrast to the stability of objects, processes are changes through time—movement, deterioration, transformation, metamorphosis, and 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, and 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.

Classes Versus Individuals

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 my 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 an integrated whole that functions in a definitive way, is a concrete particular, and has a beginning and end. 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 can think of the organism as the medium for the behavior—thus, if we are trying to be precise and avoid confusion, we say the behavior occurs in the organism, even though the usual construction of saying, "The organism did such-and-such," is much easier.

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 is not behavior, because the heart is only a part of the organism (see Axiom 1). 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. 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.

Conclusion

Behavior takes time. This fundamental principle for understanding behavior is supported both by logic and by theory. 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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