

Driven by Consequences: The Multiscale Molar View of Choice

William M. Baum*

University of California, Davis, Davis, CA, USA

In the Multiscale Molar View of behavior, all behavior is seen as choice and is measured as time allocation. Because time is limited, activities compete for the limited time available. When Phylogenetically Important Events (PIEs) that ultimately affect fitness and ontogenetic proxies of these PIEs occur as consequences of an activity, they drive time spent in that activity. Time allocation is studied in the laboratory with concurrent payoff schedules, in which two or more schedules operate simultaneously. The generalized matching law describes choice in relation to relative consequences. It has been verified for food and other PIEs and for pairs of variable-interval schedules and variable-interval schedules paired with variable-ratio schedules. Because behavior produces consequences in the environment and those consequences in turn affect behavior, the environmental feedback functions and behavioral functional relations may be characterized as a feedback system. When different activities produce different consequences, choice depends also on the substitutability of the consequences. When consequences are perfectly substitutable, exclusive preference may occur, but when they are imperfectly substitutable, partial preferences may occur. Choice may become a dilemma pitting impulsivity against self-control when consequences are not stationary with respect to time. Evaluated in short timeframes, an activity may be strongly induced by its consequences, but evaluated in long timeframes, its consequences may be extremely negative; such an activity (e.g., using cocaine or lying) is a bad habit. A good habit (e.g., tooth brushing or helping others) presents the opposite conflict: bad consequences in short timeframes and positive consequences in long timeframes. Research on choice between good and bad habits may reveal factors that increase time spent in good habits relative to time spent in bad habits. The Multiscale Molar View helps to clarify various complexities that underlie choice viewed as time allocation. Copyright © 2015 John Wiley & Sons, Ltd.

All behavior entails choice. Whatever an organism's situation, more than one activity is always possible. Even in the laboratory, one cannot create a situation so impoverished that only one activity is possible (Herrnstein, 1970). Moreover, in any significant period of time, several activities occur actually. Thus, choice may be understood as an allocation of behavior among several or many activities. This approach to

studying behavior is the Multiscale Molar View of behavior (Baum, 1973; 1981; 1989; 2002; Baum, 2004; Baum, 2012a; Baum, 2013).

The Multiscale Molar View contrasts with the traditional view, which takes behavior to consist of discrete responses that are strengthened by an immediately following reinforcer. The traditional view, though useful in its time, is implausible and unwieldy, not only when discussing everyday behavior but also even when studying behavior in the laboratory (Baum, 2012a; 2013). For example, how would one identify a

*Correspondence to: 611 Mason #504, San Francisco, CA 94108, USA. E-mail: wbaum@sbcglobal.net

discrete response for an activity like watching television or a rat's licking, biting, and chewing of a response lever (Baum, 1976)? How would one plausibly explain that a person works for a salary if reinforcers must be immediate? Instead, the Multiscale Molar View takes behavior to consist of temporally extended activities that are selected by their covariance with temporally extended consequences and induced or driven by those consequences (Baum, 2012a; 2013). In this view, choice—the allocation of behavior among activities—is fundamental.

A simplification that has proven successful takes the allocation of behavior to be the allocation of time among activities (Baum, 1973; 2010; Baum, 2012b; Baum & Rachlin, 1969). For example, one might represent a person's allocation of time among life activities as in Figure 1, which shows time allocation among four major activities across several weekdays. An adult with a family spends time in activities that maintain health (e.g., exercise, eating, and sleeping),

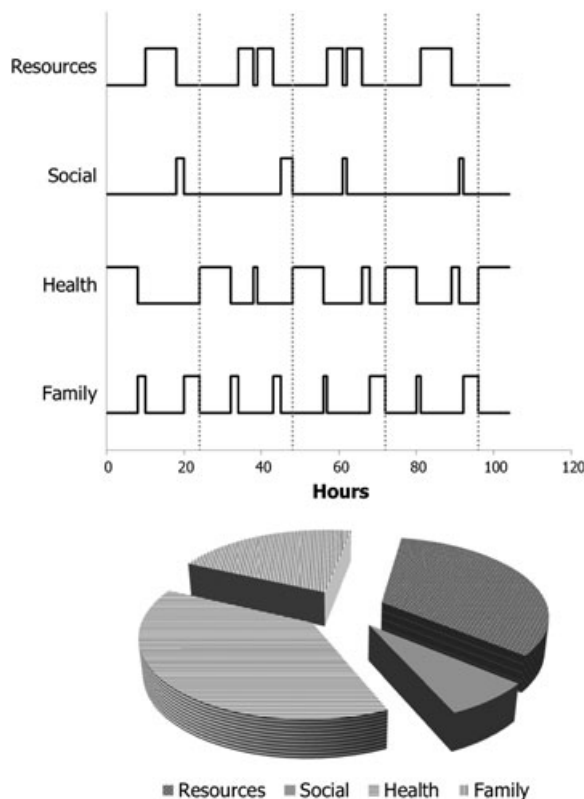


Figure 1. Hypothetical time allocation among four activities: gaining resources, socializing, maintaining health, and engaging with family. Top: Time lines show episodes (high portions) of each activity. Dotted lines mark every 24 h.

Bottom: summary of time spent during the period of observation.

activities that gain resources (e.g., working and shopping), activities that maintain relationships with others (e.g., socializing and chatting), and activities that promote reproduction (e.g., sexual and other interacting with one's spouse and caring for children). The top panel in Figure 1 shows the activities occurring in episodes through time. The bottom panel shows a summary of time spent in the activities during the span shown in the top panel.

Since time is limited, because a day contains only 24 h or a period of measurement is of a definite length, time allocation like that in Figure 1 implies that activities compete for time. If one activity increases, others must decrease. In everyday life, the competition leads to tension among activities and to dynamics in which adjustments occur across spans of time. For example, time management becomes an important skill, and 'work-life balance' becomes an important issue. A songbird's time allocates dynamically among foraging for prey and nest material, protecting a territory and a mate, feeding nestlings, and avoiding predators. Every creature lives on a time budget (e.g., Barnard, 1980).

Activities compete because of the consequences they produce. The songbird must spend time foraging because foraging produces food, and it must spend time in vigilance because vigilance avoids predators. Likewise, a human must spend time working because working produces resources and must spend time in other activities such as maintaining relationships because relationships avoid isolation and instability. The consequences and antecedents that drive or induce behavior do so ultimately as a result of evolutionary history; they are Phylogenetically Important Events (PIE; Baum, 2005; 2012a). PIEs that tend to enhance reproductive success, like resources, mates, and shelter, may be called 'good'. PIEs that tend to diminish reproductive success, like predators, illness, and injury, may be called 'bad'. Both good and bad PIEs induce activities specific to them. Good PIEs induce behavior that makes them likely to remain or occur; bad PIEs induce behavior that makes them unlikely to remain or occur. The influences of culture and individual experience that increase activities that make good PIEs more likely and bad PIEs less likely depend ultimately on evolutionary history with respect to those PIEs. A neutral object or event becomes a proxy for a PIE when it covaries with the PIE, as, for example, money covaries with resources. The covariance selects money from other environmental objects and events, and once money becomes a proxy, it induces activities like shopping or working much as the resources themselves would. Whether we consider food

or predators, a mate or an injury, the relevant activities are induced by the PIEs themselves or their proxies (money, alarm, flirtation, weapons, etc.), and the activities compete for time. [For further discussion, see Baum (2005; 2012a).]

The Matching Law

In the laboratory, choice as behavioral allocation has been studied extensively in a variety of species, including rats, monkeys, pigeons, and humans [see Baum (1979) and Davison & McCarthy (1988) for reviews]. Figure 2 shows the results of a typical experiment. A pigeon was exposed to several situations, each presenting two keys continuously at which the pigeon could peck, each for enough daily sessions until no further systematic change in allocation could be seen. Pecking at the keys occasionally produced food, according to irregular time-based schedules (variable-interval schedules), and the food rate differed between the two keys, sometimes by as much as 100:1 or more. Each point shows the stable allocation of pecks between keys as a function of the allocation of food between the keys.

The regression line in Figure 2 has the following equation (Baum, 1974):

$$\log \frac{B_1}{B_2} = s \log \frac{r_1}{r_2} + \log b \tag{1}$$

where B_1 and B_2 are the times spent pecking at keys 1 and 2 measured as numbers of pecks, r_1 and r_2 are the food rates delivered by pecking at keys 1 and 2, s is sensitivity to variation in the food ratio, and b measures any bias due to factors other than food rate. Equation (1) is known as the matching law. When s and b both equal 1.0, perfect matching of behavior ratio to food ratio occurs. Often, however, sensitivity to food ratio falls short of 1.0, as in Figure 2, where s equals 0.8. Although the behavior ratio tracks the food ratio across situations, it often falls a bit short of equaling the food ratio, a result known as *undermatching* (Baum, 1974).

Research on the matching law has examined consequences other than food, varying deprivation, qualitatively and quantitatively different consequences across keys, penalties for switching between keys, and frequency of changing food ratios.

Although most of the research on the matching law concerns just two alternative activities, some has studied allocation among three or more alternatives (e.g., Aparicio & Cabrera, 2001; Schneider & Davison, 2005; Jensen & Neuringer, 2009; Jensen, 2014). One may generalize Equation (1) to any number of alternatives n as follows. The general arithmetic version of Equation (1) is a power function:

$$\frac{B_i}{B_j} = \frac{b_i r_i^{s_i}}{b_j r_j^{s_j}} \tag{2}$$

where b_i/b_j replaces b , r_i and r_j are rates of consequences not necessarily food, s_i and s_j are possibly unequal, and i and j denote two alternatives out of n alternatives.

For any alternative i , we may multiply together its ratios with respect to itself and all of the alternatives j :

$$\prod_{j=1}^n \frac{B_i}{B_j} = \prod_{j=1}^n \frac{b_i r_i^{s_i}}{b_j r_j^{s_j}}$$

Taking the logarithm of this equation, we arrive at a working equation:

$$\log B_i - \frac{1}{n} \sum \log B_j = s_i \log r_i - \frac{1}{n} \sum s_j \log r_j - \frac{1}{n} \sum \log b_j \tag{3}$$

The matching law succeeds as a description of behavioral allocation, but where does it come from? A number of derivations from more basic principles have been proposed, but the law has also been

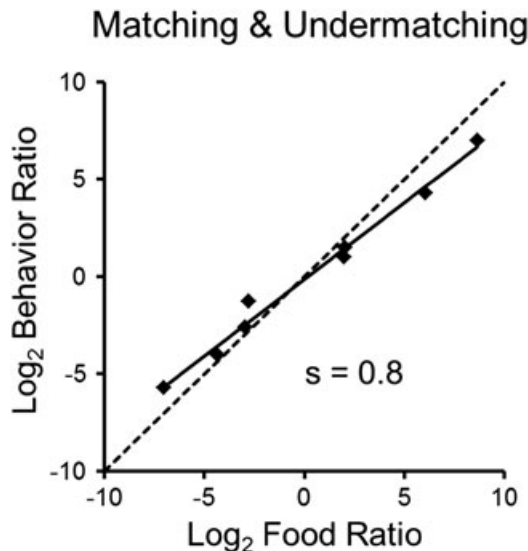


Figure 2. The generalized matching law. Points show results for one pigeon in a typical experiment with pairs of VI schedules. The solid line shows the least-squares regression line, with slope equal to 0.8. The broken line shows the locus of strict matching.

suggested to be basic itself (e.g., McDowell, 1986; Gallistel et al., 2007).

A possibility that might reconcile all speculation about the origins of the matching law would be that the power functions that comprise it are the basic relations that underlie it. If r represents the rate of a PIE (e.g., food, mate, and shelter), and a PIE induces the activity that produces it ('operant' activity), then the function governing the induction of any activity B_i that produces r_i might be

$$B_i = b_i r_i^s \tag{4}$$

This possibility was suggested early (Baum & Rachlin, 1969; Killeen, 1972; Rachlin, 1971) and has received some empirical support recently (Baum & Davison, 2014).

If correct, Equation (4) would fit well with the recognition that behavior and environment together constitute a feedback system.

The Behavior-environment Feedback System

Behavior produces effects in the environment, and those changes to the environment in turn affect behavior. If the world is arranged so an activity (e.g., shopping or foraging) produces a good (e.g., food or prey), the good produced also induces the activity—break either of these relations, and the activity is no longer maintained. This interlocking is characteristic of a feedback system (Baum, 1973; 1981; 1989; 2012a).

Figure 3 diagrams the behavior-environment feedback system in a rudimentary way. It shows the system in the most general terms. The activity B governs r according to a feedback function, $f(B)$, which is a characteristic of the environment, and r feeds back to the organism to induce the activity according to a

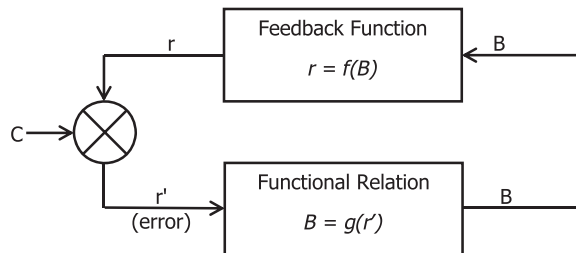


Figure 3. The behavior-environment feedback system. The upper half shows activity B affecting the environment to produce feedback r (e.g., reinforcer rate). The criterion C indicates the competition with other activities that limits effective r to r' . The lower half indicates the organism's contribution: a functional relation with r' as input and activity B as output.

functional relation, $g(r')$, perhaps like Equation (4). The criterion C sets limits to r and depends on the other activities that compete with B ; r' represents this constrained effective rate. The time spent in the activity (B) is the output from the organism. Depending on the feedback function and other activities present, B may stabilize, maintaining equilibrium.

Up to now, the discussion of the matching law focused on situations in which the alternatives constituted variable-interval (VI) schedules, in which time has to pass before the activity can produce food, thereby setting an upper limit to r . The curves in Figure 4 show some examples of VI feedback functions. An approximate equation for these curves (Baum, 1992) is

$$r = \frac{1}{t + \frac{a}{B}} \tag{5}$$

where t is the average interval required to set up food and a is a constant reflecting length of bouts of the activity. As B increases, r approaches an upper limit of $1/t$.

Plotted in the coordinates of Figure 4, the power function in Equation (4), with s less than or equal to 1.0, would pass through any number of these VI feedback functions. (If s is greater than 1.0, it will still pass through some, depending on t , b , and s .) Thus, if the n alternatives in Equation (3) are all VI schedules or

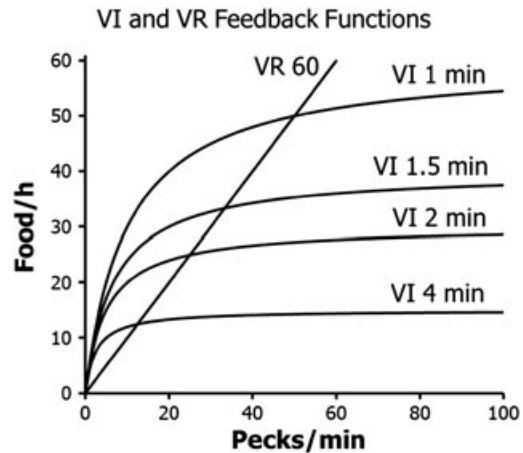


Figure 4. Typical feedback functions. The curves show feedback functions for a pigeon pecking a response key paying off according to a VI schedule. The straight line illustrates the feedback function for a VR 60 schedule: direct proportionality. VI schedules model situations in which payoff rate is limited by some uncontrollable factor (e.g., time). VR schedules model situations in which labor alone is effective.

entail negatively accelerated feedback functions like those in Figure 4, then the matching law applies.

Ratio Schedules

The situation is different for ratio schedules, which model feedback relations in which only labor counts—for example, gambling or hunting. A ratio includes no time dependency and specifies that r is directly proportional to B . The feedback function for a ratio schedule is

$$r = \frac{B}{v} \quad (6)$$

where v is the average time spent in activity B required for payoff. The straight line in Figure 4 shows a feedback function for a variable-ratio (VR) schedule—a situation in which payoff requires an uncertain amount of time spent in B .

If a fixed VR schedule is paired with various VI schedules, matching still is possible, and experiments show that it occurs, but with a constant bias in favor of the VR schedule (Herrnstein & Heyman, 1979; Heyman & Herrnstein, 1986; Baum & Aparicio, 1999). An exception occurs if the VI schedule is richer than the VR schedule, because preference tends then to favor the VI exclusively (Baum & Aparicio, 1999).

If a fixed VI schedule is paired with various VR schedules, optimality predicts substantial undermatching, but experiments so far support matching instead (Herrnstein & Heyman, 1979; Baum, 1981; Heyman & Herrnstein, 1986).

Because B equals rv in a VR schedule, we may substitute for B in Equation (2) or (3) and discover that if the alternatives are both ratio schedules the ratio r_i/r_j is constant—i.e., unaffected by B_i/B_j . If v_i equals v_j , no preference can be predicted. To predict the outcome if v_i and v_j are unequal, suppose that the ratio on the right side of Equation (2) is greater than 1.0—i.e., alternative i is richer, which means v_i is smaller than v_j , and r_i/B_i is greater than r_j/B_j . Whatever B_i/B_j equals, the only corrective action that will tend toward the relation in Equation (2) is for B_i to increase and B_j to decrease. The inequality never goes away, and eventually all time is allocated to B_i and none to B_j . The exclusive preference for B_i satisfies Equation (2) trivially, because both sides become indeterminate. By extension, Equation (3) cannot be met if the alternatives are all VR schedules, because the richest schedule will attract all the time (Herrnstein & Loveland, 1975). The prediction of exclusive preference,

however, depends on all the alternatives producing the same outcome.

Substitutability and Partial Preferences

Up to now, all the results we have considered occurred in experiments in which the alternative activities produced the same (identical) outcome—generally, the same opportunity to eat. Identical goods guarantee perfect substitutability, but in the world outside the laboratory, the products of our activities are often imperfectly substitutable. When will I give up some peanut butter for some jam? Some clothes for some money? Some money for some love?

Some experiments have studied choice between qualitatively different outcomes. Miller (1976), for example, studied pigeons' behavioral allocation between pairs of VI schedules that produced different grains. The results conformed to Equation (1) with the difference only contributing to bias (b not equal to 1.0), suggesting unequal b_i and b_j in Equation (2). Hollard and Davison (1971) obtained similar results studying VI schedules that paid off with food and electrical brain stimulation. When only bias is affected, the two qualitatively different outcomes would be completely substitutable.

Some studies have been done of concurrent VR schedules with qualitatively different outcomes (e.g., Green & Rachlin, 1991; Green & Freed, 1993; Belke, Pierce, & Duncan, 2006). In research on foraging, however, numerous experiments on dietary choice have been done (e.g., Krebs & Davies, 1993). Foraging may be thought of as equivalent to a ratio schedule, because the more time is spent, the more prey are obtained. Optimal diet theory in its simplest form took calories as a currency and ignored other nutrients that might affect preference for various prey. As a result, early optimal diet theory predicted exclusive preference for a more calorie-rich prey item when a forager is given a choice. Instead, researchers found partial preferences, implying that the different preys could not be measured on a single currency and were imperfectly substitutable.

Doubtless, different prey items contain different nutrients, any of which might be crucial to a health-maintaining diet. If we think of all the different nutrients required, we may conceive of them as complements, at least when any of them is scarce (Rapport, 1980; 1981). If a forager requires calcium and the usual prey is deficient in calcium, the forager will switch when a rare calcium-rich prey item appears and may for a time prefer such prey exclusively.

Switching among prey produces partial preferences. Partial preferences occur also with concurrent VR schedules in the laboratory, if the different schedules produce imperfectly substitutable outcomes. Preference in a situation like that might tend to be optimal, just as performance on concurrent VI schedules tends to be optimal, but the two situations generate switching for different reasons. In concurrent VI schedules, switching occurs because time spent with one schedule results in higher likelihood of reward from the other schedule (Rachlin, Green, & Tormey, 1988). In concurrent VR schedules, switching would depend on non-substitutable outcomes. For example, rats' choice between food and water cannot be exclusive, although Rachlin and Krasnoff (1983) found evidence that when water is easily available, drinking may substitute to a degree for eating. Belke, Pierce, and Duncan (2006) found evidence of substitutability between sucrose and wheel running in rats. A version of Equation (2) describes substitutability and complementarity, with the exponent indicating degree of substitutability or complementarity (Green & Freed, 1993; Green & Rachlin, 1991, Equation (4)).

Impulsivity, Self-control, and Time Allocation

Up to this point, the discussion has assumed that the inducing consequences of an activity are stationary with respect to time. Apart from increasing variability with smaller sample sizes, whether we measure a pigeon's time allocation between concurrent VI schedules for 20 min or 3 h makes no difference to the choice relation. A person's time allocation between work and family might remain the same whether measured for a month or a year. Some activities, however, change consequences depending on the timeframe within which they are evaluated. In the short term, eating candy, chips, and soda may be strongly induced, because these junk foods stimulate receptors for sweet, salt, and fat, but in the long term, consuming junk food has bad consequences, because a diet heavy with junk food leads to health problems and early death. Similarly, activities like smoking, drinking alcohol, injecting heroin, spending money, lying, cheating, and crime may be strongly induced in the short term and have bad consequences in the long term. Conversely, putting off visiting the dentist may be strongly induced in the short term, because it takes time and may be uncomfortable and painful, but in the long term, visiting the dentist helps maintain health and prolong life. The same pattern holds for activities like saving money, paying taxes, cooperating with other

people, helping strangers, and using public transit: In the short term, their consequences induce avoidance, but in the long term, they have good consequences. In all these examples, when the activity shifts consequences with timeframe, the better alternative is the one that produces better long-term consequences, but the long-term consequences are weakly inducing in competition with short-term consequences that are strongly inducing. Money in the bank is weakly inducing in competition with money in the hand, public transit is weakly inducing in competition with taking one's own car, and the benefits of sobriety are weakly inducing in competition with a drink available immediately.

Activities like eating junk food and smoking may be called 'bad habits', and activities like visiting the dentist and saving money may be called 'good habits'. Figure 5 illustrates how a bad habit affects quality of life and changes consequences with timeframe. The top graph indicates the decrease in quality of life to expect with the passage of time from the inception of the bad habit when the activity occurs at a low, medium, or high rate. Low time allocation to an activity like drinking alcohol has little deleterious effect on quality of life—and might even enhance it—but a medium allocation (say, heavy drinking on weekends) reduces quality of life (possibly hurting health, job performance, and losing friends), and a high allocation (daily drunkenness) lowers quality of life hugely by effects like losing one's job, spouse, friends, house, and health. A person who is addicted to alcohol, heroin, pornography, or gambling engages in the bad habit at a high rate and suffers the loss. The dotted line suggests the long-term relation between activity rate or time allocation and loss in quality of life; loss accelerates with rate.

The lower graph in Figure 5 illustrates the dependence of the consequences of a bad habit on the timeframe in which it is evaluated. The vertical axis goes in the opposite direction to that of the upper graph. Consequences on the vertical axis range from positive to negative (good to bad). The horizontal axis indicates the timeframe over which the consequences are calculated; it is in days and is logarithmic to consider timeframes on the order of a day up to timeframes of months or years. Eating junk food or snorting cocaine has high positive consequences for a matter of hours, but when pursued repeatedly over a longer timeframe, its consequences shift to negative—less negative for a low rate, more negative for a medium or high rate.

A bad habit presents the problem that short-term consequences conflict with long-term consequences. Because of genetics and environmental effects (i.e., life

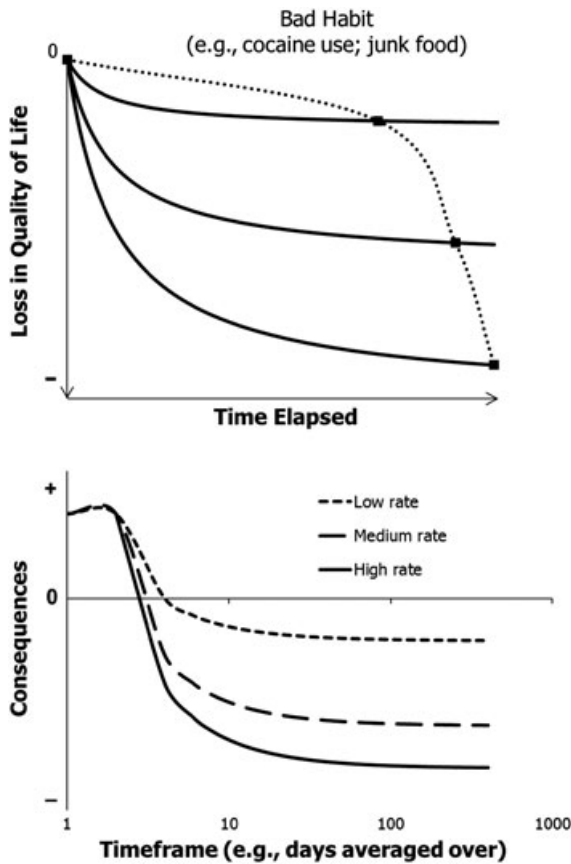


Figure 5. Effects and challenges of a bad habit. Top: Loss in quality of life (downward into negative y-axis) of three different rates of time spent in a bad habit as time goes by. The upper curve shows loss due to a low rate, the middle curve shows loss due to a medium rate, and the lower curve shows the large loss due to a high rate. The dotted curve connects points at which loss reaches 90% of asymptotic loss and suggests that loss accelerates with rate of time spent in the bad habit. Bottom: Conflict of timeframes results from a shift from positive (good) consequences of the bad habit in short timeframes to negative (bad) consequences of the bad habit in long timeframes. Evaluated over a day or two, snorting cocaine might have positive consequences, but evaluated over many days, its bad consequences reduce quality of life.

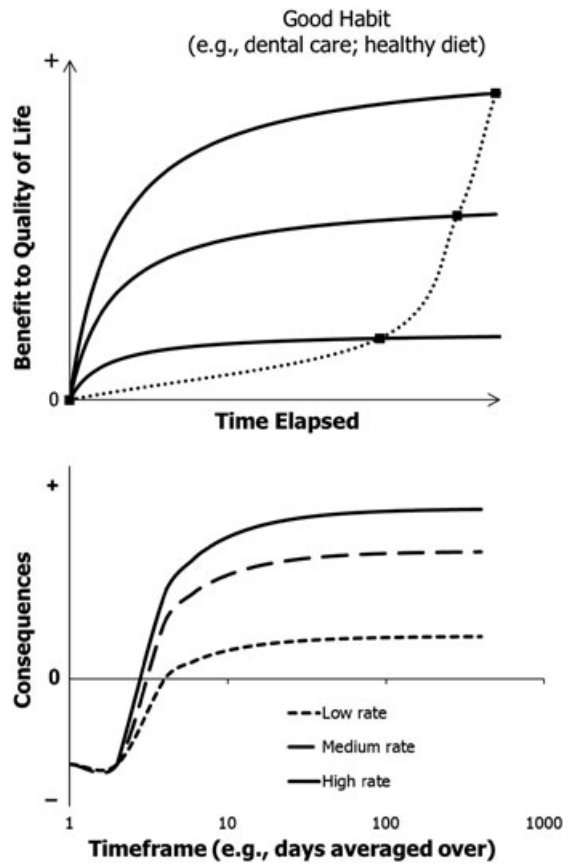


Figure 6. Effects and challenges of a good habit. Top: Benefit to quality of life (upward into positive y-axis) of three different rates of time spent in a good habit as time goes by. The lower curve shows benefit of a low rate, the middle curve shows benefit of a medium rate, and the upper curve shows the high benefit of a high rate. The dotted curve connects points at which benefit reaches 90% of asymptotic benefit and suggests that benefit accelerates with rate of time spent in the good habit. Bottom: Conflict of timeframes results from a shift from negative consequences of the good habit in short timeframes to positive consequences of the good habit in long timeframes. Evaluated over a day or two, the bad consequences of going to the dentist might induce procrastination, but evaluated over many days, visiting the dentist has good consequences in benefits to health.

history), some people’s behavior fails to come into contact with the long-term effects on quality of life, and those people suffer. They may be trained, however, in the long-term contingencies—alcoholics and other addicts sometimes can learn to abstain, spend-thrifts can learn to save, gamblers can quit, and criminals can go straight.

Figure 6 illustrates how a good habit affects quality of life and changes consequences with timeframe. The top graph indicates how the benefit to quality of life

increases with time elapsed since the inception of the good habit—less for a low rate or time allocation, more for a medium rate or allocation, and most for a high rate or allocation. Caring for one’s teeth or eating fruits and vegetables, if infrequent, may slightly increase health and well-being, but if engaged in more often, they increase quality of life more. The dotted line suggests the relation between benefit in quality of life and rate or time allocated to the good habit; benefit accelerates with rate.

The lower graph in Figure 6 illustrates the way a good habit's consequences change with the timeframe over which they are evaluated. The axes are the same as in the lower graph in Figure 5. The good habit typically has negative (bad) consequences when evaluated over a timeframe on the scale of a day, but evaluated on scales of days, months, or years, its consequences shift to positive (good)—less positive if its rate is low and most positive if its rate is high.

A good habit presents the opposite problem to a bad habit. Short-term consequences conflict with long-term consequences, but in the opposite direction. Saving money or helping a stranger is bad in the short term, but enhances one's quality of life in the long term, because one may have money when it is needed or because one may live in an environment where people help one another when in need. As with bad habits, some people's behavior, because of genetics or life history, may fail to come into contact with the long-term contingencies between the good habit and its benefits. As with bad habits, those people may be trained in the long-term benefits. If they missed it in preschool, they can sometimes be taught to cooperate and plan ahead as adults.

This way of thinking about good and bad habits is not usual (but see Rachlin, 1995a; 2000; 2002; Rachlin & Locey, 2011). Impulsivity (i.e., bad habits) and self-control (i.e., good habits) are most often thought of as depending on temporal discounting or probability discounting. Experiments on discounting typically give a subject choices between two outcomes, one constant and usually immediate (e.g., 10 dollars now) and one that varies from choice to choice in either delay or probability (e.g., 100 dollars in a week or 100 dollars with a probability of .5). As the delay or probability varies across choices, a delay or probability is found for which the subject is indifferent between the two amounts. The immediate amount is taken as the measure of the delayed or probabilistic amount. This procedure is repeated for several different immediate amounts, and indifference points may be analyzed as a function of delay or odds-against transformation of probability (e.g., Green & Myerson, 2013; Green, Myerson, Oliveira, & Chang, 2014).

Experiments on discounting afford a way to measure impulsivity by equating it to degree of discounting. They have been popular because they allow one to study the environmental factors that favor impulsivity over self-control. Addicts, for example, often discount more steeply than non-addicts (see Odum, 2011, for overview). One great benefit the experiments may offer would be to understand the

environmental factors or therapeutic procedures that would shift control of behavior from short-term timeframes to long-term. Figure 3 indicates that the consequences of an operant activity induce the activity that produces them (i.e., r feeds back to the activity B), but the diagram specifies nothing about timeframe. It applies to the addict's injecting heroin and the effects of the heroin inducing continued injecting as much as to eating a good diet and the good health inducing continued healthful eating. Future research might suggest ways to shift the addict's behavior from short-term control by short-term benefits to long-term control by long-term benefits, and some research has already addressed the problem (Mazur & Logue, 1978; Rachlin, 1995b; Locey & Rachlin, 2012, 2013).

Although experiments on discounting may offer a measure of impulsivity or self-control, how they relate to the real-world extended behavioral patterns of bad habits and good habits remains unclear. The outcomes in experiments on discounting are invariably discrete events like receiving 10 dollars or 100 dollars, because only discrete events can be unambiguously delayed or probabilistic. Real-world outcomes, however, rarely consist of discrete events. Good health cannot arrive suddenly after a delay nor can it usually be lost suddenly one day. Instead, real-world outcomes are extended conditions like sobriety, contributing to the welfare of others, having a good marriage, having a growing bank account, and enjoying the admiration of others. None of these can reasonably be considered delayed or probabilistic, because they extend through time. A bad habit or a good habit, though extended in time, might be thought of as a pattern of many choices that were discrete, but the extended habit pattern also has extended consequences, as suggested by the feedback system represented in Figure 3. Discounting experiments seem to have little to do with such temporally extended relations (Rachlin, 1995a; 2002). How one might model extended outcomes with discounting experiments remains to be seen (see Heyman, 2009 and Rachlin, 2000 for extended discussions).

CONCLUSION

The Multiscale Molar View taken in this paper affords accounts of behavior that are simple, elegant, and plausible. These natural-science accounts are actually or potentially quantitative, as illustrated by the matching law, and they omit anti-scientific concepts like free will and agency (Baum, 1995; 2005). Additionally, the

Multiscale Molar View ties the study of behavior directly to evolutionary theory by means of PIEs and the activities they induce. The concept of reinforcement takes a different form, because instead of strengthening activities they follow, PIEs induce behavior on which they are contingent (Baum, 2012a). The present paper focused on choice, but because all behavior entails choice, the treatment of choice is the treatment of behavior in general. Taking choice as the allocation of time among competing activities offers a general framework for understanding the behavior of humans and other animals, including choice between qualitatively different outcomes and self-control.

Acknowledgement

The author thanks Howard Rachlin for many helpful comments.

REFERENCES

- Aparicio CF, Cabrera F. 2001. Choice with multiple alternatives: the barrier choice paradigm. *Mexican Journal of Behavior Analysis* **27**: 97–118.
- Barnard CJ. 1980. Flock feeding and time budgets in the house sparrow (passer domesticus). *Animal Behavior* **28**: 295–309.
- Baum WM. 1973. The correlation-based law of effect. *Journal of the Experimental Analysis of Behavior* **20**: 137–153.
- Baum WM. 1974. On two types of deviation from the matching law: bias and undermatching. *Journal of the Experimental Analysis of Behavior* **22**: 231–242.
- Baum WM. 1976. Time-based and count-based measurement of preference. *Journal of the Experimental Analysis of Behavior* **26**: 27–35.
- Baum WM. 1979. Matching, undermatching, and overmatching in studies of choice. *Journal of the Experimental Analysis of Behavior* **32**: 269–281.
- Baum WM. 1981. Optimization and the matching law as accounts of instrumental behavior. *Journal of the Experimental Analysis of Behavior* **36**: 387–403.
- Baum WM. 1989. Quantitative prediction and molar description of the environment. *The Behavior Analyst* **12**: 167–176.
- Baum WM. 1992. In search of the feedback function for variable-interval schedules. *Journal of the Experimental Analysis of Behavior* **57**: 365–375.
- Baum WM. 1995. Radical behaviorism and the concept of agency. *Behaviorology* **3**: 93–106.
- Baum WM. 2002. From molecular to molar: a paradigm shift in behavior analysis. *Journal of the Experimental Analysis of Behavior* **78**: 95–116.
- Baum WM. 2004. Molar and molecular views of choice. *Behavioural Processes* **66**: 349–359.
- Baum WM. 2005. Understanding Behaviorism: Behavior, Culture, and Evolution (2nd edn), Blackwell Publishing: Malden, MA.
- Baum WM. 2010. Dynamics of choice: A tutorial. *Journal of the Experimental Analysis of Behavior* **94**: 161–174.
- Baum WM. 2012a. Rethinking reinforcement: allocation, induction, and contingency. *Journal of the Experimental Analysis of Behavior* **97**: 101–124.
- Baum WM. 2012b. Mathematics and theory in behavior analysis: remarks on Catania (1981), “the flight from experimental analysis.” *European Journal of Behavior Analysis* **13**: 177–179.
- Baum WM. 2013. What counts as behavior: the molar multiscale view. *The Behavior Analyst* **36**: 283–293.
- Baum WM, Aparicio CF. 1999. Optimality and concurrent variable-interval variable-ratio schedules. *Journal of the Experimental Analysis of Behavior* **71**: 75–89.
- Baum W. M. 2014. Choice with frequently-changing food rates and food ratios. *Journal of the Experimental Analysis of Behavior* **101**: 246–274.
- Baum WM, Davison M. 2014. Choice with frequently-changing food rates and food ratios. *Journal of the Experimental Analysis of Behavior* **101**: 246–274.
- Baum WM, Rachlin HC. 1969. Choice as time allocation. *Journal of the Experimental Analysis of Behavior* **12**: 861–874.
- Belke TW, Pierce WD, Duncan ID. 2006. Reinforcement value and substitutability of sucrose and wheel running: implications for activity anorexia. *Journal of the Experimental Analysis of Behavior* **86**: 131–158.
- Davison M, McCarthy D. 1988. The Matching Law: A Research Review. Erlbaum Associates: Hillsdale, NJ.
- Gallistel CR, King AP, Gottlieb D, Balci F, Papachristos EB, Szalecki M, Carbone KS. 2007. Is matching innate? *Journal of the Experimental Analysis of Behavior* **87**: 161–199.
- Green L, Freed DE. 1993. The substitutability of reinforcers. *Journal of the Experimental Analysis of Behavior* **60**: 141–158.
- Green L, Myerson J. 2013. How many impulsivities? A discounting perspective. *Journal of the Experimental Analysis of Behavior* **99**: 3–13.
- Green L, Myerson J, Oliveira L, Chang SE. 2014. Discounting of delayed and probabilistic losses over a range of amounts. *Journal of the Experimental Analysis of Behavior* **101**: 186–200.
- Green L, Rachlin H. 1991. Economic substitutability of electrical brain stimulation, food, and water. *Journal of the Experimental Analysis of Behavior* **55**: 133–143.
- Herrnstein RJ. 1970. On the law of effect. *Journal of the Experimental Analysis of Behavior* **13**: 243–266.
- Herrnstein RJ, Heyman GM. 1979. Is matching compatible with reinforcement maximization on concurrent variable interval, variable ratio? *Journal of the Experimental Analysis of Behavior* **31**: 209–223.
- Herrnstein RJ, Loveland DH. 1975. Maximizing and matching on concurrent ratio schedules. *Journal of the Experimental Analysis of Behavior* **24**: 107–116.
- Heyman GM. 2009. Addiction: A Disorder of Choice. Harvard University Press: Cambridge, MA.
- Heyman GM, Herrnstein RJ. 1986. More on concurrent interval-ratio schedules: a replication and review. *Journal of the Experimental Analysis of Behavior* **46**: 331–351.
- Hollard V, Davison MC. 1971. Preference for qualitatively different reinforcers. *Journal of the Experimental Analysis of Behavior* **16**: 375–380.

- Jensen G. 2014. Compositions and their application to the analysis of choice. *Journal of the Experimental Analysis of Behavior* **102**: 1–25.
- Jensen G, Neuringer A. 2009. Barycentric extension of generalized matching. *Journal of the Experimental Analysis of Behavior* **92**: 139–159.
- Killeen P. 1972. The matching law. *Journal of the Experimental Analysis of Behavior* **17**: 489–495.
- Krebs JR, Davies NB. 1993. *An Introduction to Behavioural Ecology* 3rd edn, Blackwell Scientific: Oxford.
- Locey M, Rachlin H. 2012. Commitment and self-control in a prisoner's dilemma game. *Journal of the Experimental Analysis of Behavior* **98**: 89–103.
- Locey ML, Rachlin H. 2013. Shaping behavioral patterns. *Journal of the Experimental Analysis of Behavior* **99**: 245–259.
- McDowell JJ. 1986. On the falsifiability of matching theory. *Journal of the Experimental Analysis of Behavior* **45**: 63–74.
- Mazur JE, Logue AW. 1978. Choice in a “self-control” paradigm: effects of a fading procedure. *Journal of the Experimental Analysis of Behavior* **30**: 11–17.
- Miller HLJ. 1976. Matching-based hedonic scaling in the pigeon. *Journal of the Experimental Analysis of Behavior* **26**: 335–347.
- Odum AL. 2011. Delay discounting: I'm a k, you're a k. *Journal of the Experimental Analysis of Behavior* **96**: 427–439.
- Rachlin H. 1971. On the tautology of the matching law. *Journal of the Experimental Analysis of Behavior* **15**: 249–251.
- Rachlin H. 1995a. Self-control: beyond commitment. *Behavioral and Brain Sciences* **18**: 109–159.
- Rachlin H. 1995b. The value of temporal patterns in behavior. *Current Directions in Psychological Science* **4**: 188–192.
- Rachlin H. 2000. *The Science of Self-control*. Harvard University Press: Cambridge, MA.
- Rachlin H. 2002. Altruism and selfishness. *Behavioral and Brain Sciences* **25**: 239–296.
- Rachlin H, Green L, Tormey B. 1988. Is there a decisive test between matching and maximizing? *Journal of the Experimental Analysis of Behavior* **50**: 113–123.
- Rachlin H, Krasnoff J. 1983. Eating and drinking: an economic analysis. *Journal of the Experimental Analysis of Behavior* **39**: 385–404.
- Rachlin H, Locey M. 2011. A behavioral analysis of altruism. *Behavioural Processes* **87**: 25–33.
- Rappoport DJ. 1980. Optimal foraging for complementary resources. *The American Naturalist* **116**: 324–346.
- Rappoport DJ. 1981. Foraging of *Stentor coeruleus*: a microeconomic interpretation. In *Foraging Behavior* Kamil AC, Sargent TD (eds). Garland Press: New York; 77–93.
- Schneider SM, Davison M. 2005. Demarcated response sequences and generalized matching. *Behavioural Processes* **70**: 51–61.