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Impetus for a Robust Science of Behavior: A Review of Nevin's Behavioral Momentum: A Scientific Metaphor

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Impetus for a Robust Science of Behavior:

A Review of Nevin's *Behavioral Momentum: A Scientific Metaphor*[1]

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Abstract

Nevin provides a scientific role model, illustrating momentum in his own research and providing impetus through his effects on the scientific behavior of his students and his colleagues. I discuss his book in the context of a review of the history of the concept of extinction, I cite his introduction of signal-detection analysis into behavior analysis as a contribution not covered in this book, I briefly consider applications, such as the potential extension to fluency procedures in education, and I critique his concept of momentum, relating it to other metaphors for maintained behavior such as the dynamics of sensory systems and robustness in biological accounts of the stability of phenotypes.

End of abstract

Tony Nevin and I share more than just our preferences to be called by our middle names rather than our first names. After completing my postdoctoral work in 1962 I took a position at the Smith Kline & French Laboratories in Philadelphia and commuted into the city by train from an apartment in the town of Swarthmore. There I had the good fortune to live not far from Tony, who was then a faculty member at Swarthmore College. We'd probably already met briefly at professional meetings, but because we shared some mentors from our days at Columbia and we were both starting families, it was probably inevitable that we'd get to know each other better in Swarthmore. It also helped that he came to behavior analysis from engineering and I came to it from mathematics, so we shared a perspective on its potential for becoming a quantitative science. We maintained contact after we both moved on. One consequence was that Tony asked me to contribute a chapter to a book he was editing (Catania, 1973; Nevin, 1973). That chapter forced me to grapple with the relation between reinforcement and extinction and was a precursor for my later texts (Catania, 1979, 2107). My work continues to be informed (perhaps too slowly) by his ongoing research. His book provides an opportunity for revisiting his contributions.

For those yet to engage extensively with Tony's research, the book is a pretty good place to start. For those and for others who've known him through his work but haven't had the privilege of knowing him personally, the book demonstrates not only his intellectual engagement with crucial issues in the foundations of behavior analysis but also his infectious enthusiasm for our science. Don't expect a homogeneous narrative. The book ranges from material on basic methods and concepts aimed at introductory readers to technical sections requiring careful reading. He considers both basic and applied implications of his work. Throughout he provides personal perspectives along with accounts of the roles his many students have played in his research.

Also, don't expect a review of the breadth of his contributions. In particular, early on in his career Tony introduced the behavior-analytic research community to signal detection, which he brought over to us from its origins in studies of sensory systems and thresholds (Green & Swets, 1966; Nevin, 1969). The stimulus as an antecedent in a three-term contingency is so much a part of our science that we would have been remiss if he hadn't enabled the use of signal-detection methodologies among our core procedures.

Signal Detection

Signal-detection theory assumes an observer responds or doesn't respond to a stimulus consisting of either a signal in noise or noise alone. Responding to the signal is a *hit*, but responding to the noise alone is a *false alarm*; not responding to the signal is a *miss*, but not responding to the noise alone is a *correct rejection*. Measures of sensitivity and bias can be derived from these basic data. Tony demonstrated how readily the analysis can be applied to discriminated responding, as when a pigeon's pecks are reinforced during green but not red; pecks on green are hits and failures to peck are misses, whereas pecks on red are false alarms and failures to peck are correct rejections.

The analysis can also be extended to the selection of responses by shaping. In shaping toward the high extreme of a response distribution, responses from the top half of the distribution should be reinforced but those from the bottom shouldn't. We can interpret the shaper's behavior as signal detection: reinforcing a response from the top of the distribution is a hit but reinforcing one from the bottom is a false alarm; not reinforcing one from the top is a miss but not reinforcing one from the bottom is a correct rejection. Tony's treatment of signal detection has tied behavior analysis inextricably to analyses of sensory systems, which in turn has tied it to the biological sciences (Catania, 2014).

Resistance to Extinction and the Evolution of a Metaphor

Consistent with its title, Tony's book concentrates on his metaphor of behavioral momentum, which was rooted in and grew out of his earlier interests. Nowadays we take it for granted that extinction provided evidence for the temporary effects of reinforcement, but in those days it was not so obvious. Early thinking about extinction and resistance to extinction regarded extinction as a special process in its own right rather than as one of the properties of reinforcement. Reinforcement and extinction were routinely covered in separate chapters in textbooks. Taken together, a conditioning vocabulary inherited from Pavlovian antecedents, which to some extent persists even now, and some peculiar properties of behavior during extinction, such as spontaneous recovery and disinhibition, supported an account of extinguished responding in terms of behavior that was somehow there all the time but inhibited.

This was the context within which we finally began to look at extinction as a process that could tell us something about reinforcement rather than as a phenomenon in its own right to be treated independently of reinforcement. The chapter I wrote for Tony's book explicitly made that point, perhaps for the first time in print, but it was a view Tony and I and George Reynolds and others had already been sharing. Furthermore, early on Skinner (1938) had of course implicitly taken that position when he eschewed appeals to inhibitory processes in accounts of the reduction of response rates during extinction. But Skinner's alternatives were complicated by the greater resistance to extinction of intermittently reinforced than of continuously reinforced responding.

With the advent of schedules of reinforcement (Ferster & Skinner, 1957), resistance to extinction became the dominant way to discuss differences in the decline of response rates over time after reinforcement is discontinued, and it sometimes served as a synonym for response strength. But it soon became clear that the concept was mired in ambiguities: either of two different extinction curves could be regarded as the more resistant to extinction depending on whether amount of responding or time to some criterion reduction was taken as the defining measure. A high-rate response might drop off precipitously given a small change in reinforcement while a low-rate one might stubbornly continue despite a major change in reinforcement. Either slow or fast response rates might be either durable or fragile given prevailing reinforcement contingencies. When response rate and resistance to extinction move in opposite directions, which should we follow?

Adding to the complexity, response rates during extinction wouldn't do as measures of strength because they could be differentially reinforced. If reinforcement contingencies can make responding either slow or fast, how can we use those rates to judge how strong the responding is? Resistance to extinction seemed a more plausible measure because it could vary independently of rate.

Another distraction was the role of superstition through accidental contiguities between responses and reinforcers (Skinner, 1948). The preponderance of evidence eventually made it clear that the behavior of organisms interacts differently with reinforcers that are consequences of behavior and those that occur independently of it (e.g., Catania, 2005). The effects of accidental contiguities are typically transient (free reinforcement can retard the course of extinction), but it took some time before procedures that involved alternative reinforcers acquired some legitimacy as tools of analysis rather than as sources of confounding superstitious behavior. That evolution was a prerequisite for the use of alternative reinforcement and its noncontingent variations in applied settings. As he developed his momentum metaphor, Tony sharpened the distinction between response rate and resistance to extinction, and the latter became a special case in the more generalized phenomena of resistance to change and their extension to a broad range of response classes, such as discriminating and attending and remembering (Nevin et al., 2003).

Perhaps the cleaning up of these conceptual issues will come to be seen as Tony's most substantial contribution to our science. Nailing down appropriate measures is a crucial component of any quantitative science. For example, Mendeleev could not have created his periodic table without organizing the elements in terms of their atomic weights rather than in terms of other properties (Gordin, 2004).

The Metaphor of Momentum

Most online dictionaries list *momentum* and *impetus* as synonyms, though technical usages distinguish impetus, an antecedent that makes something happen, from its consequence, momentum, the quantity of motion produced by this antecedent. In this technical usage, what is moved is mass. If we translate to behavior-analytic usage and fulfill the ABCs of the three-term contingency, mass is equivalent to behavior. In physics, these relations are captured by Newton's second law, in the equation $\Delta v = f/m$, where Δv is change in velocity, f is imposed force or impetus, and m is mass. Momentum is the product of velocity and mass.

According to multiple web sources, commonly accepted synonyms for impetus include cause, impulse, occasion and stimulus. Those for momentum include energy, force and power. Those for both include drive, motive force and strength. At one time or another accounts of behavior have incorporated all of these terms among their metaphors.

Tony concisely summarizes his extension of these relations to behavior almost halfway into the book: "…you can't tell which of two ongoing responses occurring at the same rate – the traditional measure of response rate – has acquired a greater propensity to keep going as a result of a history of reinforcement until you challenge or disrupt responding in some way. More importantly, the persistence of ongoing responding is separable from its rate" (Nevin, 2015, p. 93). He then introduces "the notion that ongoing response rate and resistance to change are determined independently by response-reinforcer and stimulus-reinforcer contingencies." (p. 93). The term "independently" is crucial, and we'll come back to it later.

Tony quantifies the behavioral account in the equation $\Delta B = -x/m$, where ΔB is a change in response rate, x is a disruptor, with a minus sign because disruptors reduce response rate, and m is an inferred quantity, behavioral mass. Disruptors include not only alternative reinforcers, aversive events, and motivational operations such as satiation, but also extinction itself.

The elaboration of these relations leads to a crucial distinction between the operant and Pavlovian determinants of resistance to change. Operant contingencies, the production of reinforcers by responses, produce response rates, but Pavlovian contingencies, the relations between stimuli and correlated reinforcer deliveries, determine resistance to change or resistance to disruption. The book presents the experimental findings that support this distinction in some detail. The distinction appears similar to that between activation or arousal, in the excitation of behavior by the delivery of reinforcers, and coupling, in the more specific effects of response reinforcer contingencies (Killeen & Bizo, 1998; Killeen & Sitomer, 2003). These accounts too sometimes appeal to physical metaphors.

Momentum in Clinical and Educational Settings

The momentum research has also led to counter-intuitive predictions in both experimental and applied settings, as in the demonstration that a side effect of the differential reinforcement of alternative behavior, often used as an adjunct to or substitute for extinction as a method for reducing behavior in clinical settings, may be an increase in resistance to extinction (Mace et al., 2010). Tony also applies these concepts to issues of broader significance, such as political action and global warming.

We may hope to see the applications extended to education. For example, arithmetic facts, spelling and other academic skills are said to be *fluent* when they have been practiced and reinforced to the point where they occur with high accuracy and short latency (Binder, 1996). Once such skills become fluent, they also become less likely to be disrupted by changes in settings or other distractions, and they are more likely to enter into spontaneous combinations, or adduction. Fluent skills, more resistant to change than those not learned to a fluency criterion, seem good candidates for interpretations in terms of momentum. Fluency is created by overtraining, in which response rate have reached a ceiling, so it cannot be assessed in terms of response rate; resistance to change is probably the appropriate measure.

What we know about fluency in educational settings is consistent with what we know about accuracy in other settings. For example, correct responses and errors in matching or oddity problems ordinarily differ in strength, and introducing reinforcers for other responses typically reduces the errors more than the correct responses (Catania & Dobson, 1972; cf. Nevin et al., 2003). Paradoxically, instead of competing with or degrading the matching or oddity performance, introducing some other concurrently reinforced response class makes the performance more accurate. In contrast to the clinical side effects of alternative reinforcers, might this be an advantageous side effect of the reinforcement of alternative behavior?

Metaphors in Physics, Biology and Behavior

The momentum equation could not be carried over from physics to behavioral systems without changes. In particular, the imposed force in physics, f, without sign, became a term that had only a negative value in its behavioral analog, $-x$ for the effect of a disruptor. The equation is therefore at best incomplete, for it has nothing to say about what gets behavior going in the first place. It also implies that, along with other variables, extinction itself is a disruptor rather than a property of reinforcement that demonstrates the impermanence of the effects of a response-reinforcer contingency. Yet would we want to extend the metaphor by, say, assuming that the medium through which the behavioral mass travels generates friction that slows it down? But of course all metaphors eventually break down if we explore them in sufficient detail.

Once a contingency has provided some impetus to a behavior mass, why should the behavior stop? Yet we know it should, because we must continue the response-reinforcer contingency to maintain reinforced behavior. Where then is the $+x$ that provides the impetus? It is tempting to look to the reinforcement terms of the matching law (Herrnstein, 1970), and Tony does indeed make use of it in some of his quantitative analyses. But the phenomena of resistance to change and those of matching have yet to be subsumed by a single unifying equation. This is no surprise if, as already quoted, they are "determined *independently* by response-reinforcer and stimulus-reinforcer contingencies" (Nevin, 2015, p. 93, my italics).

Biology sometimes provides useful analogies, so perhaps it may be appropriate to move from physical to biological metaphors. Let's begin with the issue of strength (a corresponding term in biology bearing on the resistance of the phenotype to change is *robustness*). If we study sensory processes, as in the visual system, we can distinguish between effects of stimuli at the level of individual receptors and those produced by interactions among those receptors. For example, the rates of firing of rods or cones vary with the duration and intensity of their stimulation by light. The adaptation of these cells to light and dark depend on the depletion and recovery of photosensitive pigments and can be studied by examining single cells. But the firing of each photoreceptor will also inhibit and be inhibited by the firing of neighboring cells. These interactions determine patterns of firings that can be studied only by examining the activity of cells in the context of the activity of the cells surrounding them (Ratliff & Hartline, 1959); they will be invisible to studies that examine cells in isolation. The two processes converge to determine the rate at which a given cell fires, but they call for independent quantitative treatments.

Now consider a behavioral analog. If the effects of reinforcers on responses are a variety of stimulation, then that stimulation might produce more or less resistance to change, but the specific rate of responding produced by the contingencies will depend not only on the reinforcers delivered but also by the interactions of this response with other responses for which reinforcers have been arranged, or, in other words, by the context in which the responding occurs. Thus, just as visual adaptations depend on the direct stimulation of receptors whereas patterns of firing across arrays of receptors depend on interactions among them, so also resistance to change may depend on direct effects of reinforcers whereas response rates and probabilities may depend on interactions among reinforced response classes. If so, the two processes call for independent quantitative treatments.

With any metaphor we may ask heuristic questions: e.g., will this metaphor give us good ideas for new experiments or new ways of looking at existing sets of data? As in relating the mathematics of signal detection to the behavior maintained by schedules of reinforcement (Nevin, 1969), the present mathematical account elegantly relates the behavior maintained by schedules to preference and other phenomena (Nevin & Grace, 2000).

The mathematics forces us to be explicit about our assumptions and their implications. But, perhaps in a manner analogous to the paradoxical relations of the wave and particle metaphors to quantum mechanics, the metaphorical parts of the account may cause difficulties. Thus, if behavior is not something set into motion by reinforcement and then left to continue on its own, we must see it as more like a vehicle that must continue to be fueled by having things constantly delivered to it. Thus, the metaphor of momentum may be more troublesome than the one with a more mundane history, i.e., the metaphor of resistance to change. Are the effects of extinction analogous to the resistance of some medium through which the behavior travels? And in what sense does behavior travel, once we have ascribed to it the property of mass?

Skinner followed a path that began with physics as its reference science, when he appealed to behavioral laws and principles derived from them (Skinner, 1938), and later moved to a perspective organically rooted to biology, in his treatment of the varieties of selection (Skinner, 1953, 1981). Perhaps it would be appropriate for the concept of momentum to follow a parallel route. Perhaps we should look to metaphors, models, and mathematics that show relations between the contingencies of selection that create classes of behavior (including the classes defined by stimuli, as in discriminative responding) and those maintaining and modifying those classes. It may be that, relative to the metaphor of momentum, the metaphor of resistance to change, with its implication that our main concern is with the rapidity with which behavior adjusts to new contingencies, will be the more lasting and the more robust metaphor. In other words, it may itself be more resistant to change than its alternatives (those others may lose their momentum).

Whichever way it turns out, Tony's work has provided the impetus. He has provided a solid foundation upon which others can build. He had done so with precision and with enthusiasm, and he has illustrated the generality of his perspective by extending it to a variety of experimental and applied domains. He has thereby exemplified the behavior of the effective scientist. We are all indebted to him for his contributions.

Footnote 1

John A. Nevin's *Behavioral momentum: A scientific metaphor* (2015: ISBN 978-1512297690) is available from *Amazon.com*. The author of this review may be contacted at *catania@umbc.edu*.

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